THE ENGINEERING RECORD
PUBLISHED WEEKLY BY THE
McGraw Publishing Company
MAIN OFFICES:
114 LIBERTY STREET, NEW YORK.
BRANCH OFFICES:
PHILADELPHIA: Real Estate Trust Bldg.
CHICAGO: 1140 Monadnock Block.
CLEVELAND: Cuyahoga Building.
LONDON OFFICE: Hastings House, Norfolk St., Strand.

SUBSCRIPTION RATES.
United States, Canada, Cuba and Mexico....$3.00 a year.
Foreign subscription .... $.00 a year.
25 shillings. 25 marks. 31 francs.
Foreign subscriptions may be sent to our London office.

NOTICE TO ADVERTISERS.

Changes in advertisements intended for a particular issue should reach the office of THE ENGINEERING RECORD on Friday of the previous week. New advertisements can be received up to noon of Wednesday of the week of issue.

NOTICE TO SUBSCRIBERS.

REMITTANCES.—Remittances should be made by check, New York draft, or money order, in favor of THE ENGINEERING RECORD.

CHANGES OF ADDRESS.—The old address should be given as well as the new, and notice should be received a week in advance of the desired change.

BACK COPIES.—No copies of issues prior to September, 1904, are kept on sale, except in bound volumes.

DATE ON WRAPPER indicates the month at the end of which subscription expires. The sending of remittances for renewal prior to that date will be much appreciated by the publishers.

CLUB RATE.—In acknowledgment of assistance rendered by subscribers in the securing of new orders, a club rate of $2.50 per annum is quoted. This rate applies to subscriptions in clubs of two or more, at least half of the names in the club to be those of new subscribers.

Entered at the New York Post-Office as Second Class mail matter.

Copyright, 1906, by the McGraw Publishing Co.

Of this issue of THE ENGINEERING RECORD 12,000 *copies are printed. Total circulation for* 1906 *to date* 370,500 *copies, an average of* 12,776 *copies per week.*

TABLE OF LEADING ARTICLES.

Engineering Organizations for Large Public Works.. 57
Concrete and Concrete Steel Column Tests at the Watertown Arsenal 57
Testing Standard Equipment.................... 58
The Baltimore Power Station.................... 58
Depressing the Tunnels Under the Chicago River... 59
A Model Turbine Power Station. (Illustrated)..... 60
Report of the State Commission on the California Earthquake 62
The East River Tunnels of the New York City Terminus of the Pennsylvania and Long Island Railroads.—II. (Illustrated) 66
Boiler Priming Caused by Poor Circulation........ 68
Operation of the Reading, England, Sewage Farm... 68
Power Plant of the New Abattoir in New York City. (Illustrated) 69
Lowering the Tunnels Under the Chicago River. (Illustrated) 73
Investigations of the Thermal Conductivity of Concrete and the Effect of Heat Upon Its Strength and Elastic Properties. (Illustrated)................. 74
The Public Service Building at Milwaukee, Wis. (Illustrated) 76
Experimental Methods as Applied to Water and Sewage Works for Large Communities.......... 80
Moving a House from Michigan to Massachusetts. (Illustrated) 83
Corrosion of Steel Bridges....................... 84
Concrete Columns 84
A Formula for Reinforced Concrete............... 84
Loading of Highway Bridges...................... 84

Engineering Organizations for Large Public Works.

The magnitude to which modern public works have attained is shown in no more marked manner than the organizations of the engineering forces required for their design, execution and administration. The greatest among older public works were undertaken with comparatively little initial work of preparation. The study of lines was made with comparatively little field work, and while the individual features of any one enterprise were worked out with a high degree of excellence, in most cases the main preparatory work preceding the awarding of contracts and their execution was surprisingly small compared with what is at present required. Even the preliminary operations of a large public work at the present time involve the organization of an extensive engineering force. The scale of examinations of all kinds before even the adoption of an aqueduct line is large, and the same observation is equally true of every other municipal work of magnitude. Not even a bridge of material length of span is now located without a most comprehensive and detailed examination by borings, both jet and diamond drill, and the location of a tunnel under such rivers as the East River and the Hudson River at New York involves practically the complete drilling of its entire location so that not only the character of the material to be pierced by the tunnel structure is known, but its condition also.

These observations bear with special emphasis on the conduct of such public work as that of the additional water supply for the city of New York, and the great bridges and tunnels being built within the municipal limits of the greater city. The engineering organization may be divided or classified into that of the office, laboratory and the field, the creation of the latter being concurrent with that of the office. This signifies that no location or character of any structure of any class can be determined until the field examinations have been essentially completed. The topography of the country may present favorable characteristics or those of an opposite nature and yet be most misleading; indeed that is usually the case. Any extended structure like that of a tunnel under a large river, or in a much more marked degree, the line of a great aqueduct like that contemplated from the Catskill regions to the city of New York, a distance of about 90 miles, requires a field force of such magnitude as to run into many hundreds in number. Not only extensive line and topographical surveys must be made, but literally those of borings both by water-jet and the diamond drill or other equivalent appliances, must reach very great numbers, and together with careful and extended geological studies must be made along the entire location. Valleys must be crossed by siphons or pressure tunnels, the construction difficulties of which increase rapidly with the depths and corresponding water pressures in them. Again, the type of aqueduct will depend largely upon the nature of sub-surface materials, and where such great aqueducts are to be built, in this case over 500,000,000 gal. daily capacity, the nature of the sub-strata must be practically known throughout its entire length. Where river crossings are made, like the one over the Hudson in this instance, a considerable number of different crossings must be studied in order to determine the most favorable, and these examinations must frequently be carried to several hundred feet depth.

The accumulation of field data must be largely systematized and treated by the office force, especially in that part of the office organization whose functions relate to the designing of the structures. A great variety of materials and a corresponding number of types of structures are available at the present time, necessitating a similar amount of office work in determining the most economical and efficient designs to meet the almost infinite variety of conditions encountered in the final construction. These studies begin with the accumulation of field data and end only with the completion of construction. The plans and specifications should be so drawn that while they are perfectly clear and explicit they may be sufficiently elastic to permit an improvement of designs with the progress of construction.

Another part of the office organization which has been developed within a comparatively few years is that of the laboratory, including chemical, physical and other tests of materials found in the location of the work, or which are to be used in the structures to be built. This is a most essential part of the office organization of modern great public works. The examination of soils and the location of reservoir sites requires the most careful attention as affecting the quality of water to be stored and a similar observation may apply to various portions of the watershed from which potable water is gathered. Again, a chemical examination of materials to be used in a great system of construction is absolutely essential for the excellence of the work. A marked instance of this class was the cement testing laboratory of the Rapid Transit Commission in the city of New York. It is a well-known fact that the cement manufacturers as well as the Commission benefited to an unusual degree by the work of the Rapid Transit Commission's laboratory. The Board of Water Supply of New York has also installed a working laboratory for the great variety of materials which it will be compelled to examine most carefully in the progress of its great work.

This general but imperfect view of the main features of an engineering organization for a large modern public work is sufficient to indicate the extremely wide and varied field which must be completely commanded by the chief engineer. Whatever may be the subordinate details of the organization as to classification of rank of the various classes of this force, the three broad divisions of office, laboratory and field are now absolutely essential. While there are sometimes marked public criticisms of the cost of such great organizations and although apparently large sums must necessarily be expended in creating such organizations prior to tangible results in works constructed, there is no more economical feature of public work than a complete and effective engineering organization. It greatly reduces cost by the attainment of the most economical structures of the necessary efficiency, and by an effective administration of the work of construction the date of completion is greatly enhanced. Experience already gained in such large works as that of the Rapid Transit Commission of the city of New York and others that might be named, show that the percentage of the total cost of construction which represents the total expenditure for engineering organization is strikingly low; indeed, it is one of the wisest expenditures of public money.

Concrete and Concrete-Steel Column Tests at the Watertown Arsenal.

In the issue of The Engineering Record a week ago there was printed an account by Mr. James E. Howard, of the results of tests of both plain and reinforced concrete columns at the Watertown Arsenal. That account contains results of great interest and of more than ordinary value. The sizes of the columns are such as to bring them practically into the class of actual construction, thus clearing them of any of the influences which ordinarily surround small-scale laboratory tests. Furthermore, the proportions of mixture and other features of these columns, especially both classes of reinforcement, that is, hoops and longitudinal bars, give the results a range of importance which can scarcely be attached to any other similar series of investigations. Although the work of this kind undertaken at the Watertown Arsenal is but partially completed, enough has been done already to indicate the establishment of certain general principles involved in the designs of concrete-steel members.

Much has been said and written about the value of what may be called lateral reinforcement by the use of bands or hoops, and various formulas, some more or less complicated, have been proposed for use in which certain assumptions are set forth, enabling the amount of banding to be taken into account in the working of ultimate stresses employed. It is obvious that bands or hoops can come into effective action only after sensible lateral strains in the concrete have been set up. The bands act to hold the concrete in place, however lean it may be. Indeed, as one extreme case, if sand were sufficiently banded, it could be made to act as a column, although it would be practically impossible to establish the thickness of the reinforcing cylinder for such a member except by actual, full-size tests. The main point, however, in connection with the banded concrete column is the fact that the banding, or hoops, cannot act until the longitudinal stresses in the concrete are of sufficient magnitude to induce lateral strains large enough to cause the concrete to press against the steel of the bands and bring the latter into action. This cannot be considered a satisfactory feature of the system of banding concrete columns, even though it is known that such banding will substantially enhance the bearing capacity of the material, as is abundantly shown by actual tests. The whole theory of the banding effect on concrete columns has been so fully set forth by Considére and others that little remains to be said, but tests of large banded concrete columns like those used by Mr. Howard throw much light upon the real action of the material and furnish the basis of some important conclusions.

One of the most valuable parts of Mr. Howard's investigations is that relating to the effect of reinforcement by longitudinal steel angle bars in the concrete columns tested. Unlike the steel bands, the function of the longitudinal reinforcement is a subject of practically exact computation, if the true ratio between the moduli of elasticity of concrete and steel be determined. Inasmuch as both parts of the column must be compressed alike the intensities of stresses will vary closely in proportion to the respective moduli of elasticity. In this type of column, therefore, the steel is in position to act with the best possible effect. The column can take no strains without the corresponding longitudinal strains in the steel angles. Furthermore, if the steel angles of these tests had been connected by lattice bars a most effective banding of the concrete enclosed within them would have been attained, with a resulting enhanced ultimate carrying power of the columns. It is to be hoped that in the future reinforced columns to be tested by Mr. Howard the angles in some of them may be latticed in the ordinary manner so as to show the effect of that class of banding.

As would naturally be expected, both the steel banding and the longitudinal steel angles added to the ultimate carrying power of the columns, although in different degrees. Inasmuch as the distribution of the reinforcement in the case of the steel angles is more rational and attained in such a manner as to act directly in sustaining load, there can be little doubt that the longitudinal reinforcement is the more effective and in most cases, at least, the most desirable. This last observation acquires much force when considerations of stiffness are combined with those of carrying capacity alone. As pointed out in Mr. Howard's description of the tests, the stiffness of columns with the longitudinal reinforcement is sensibly superior to that of the banded columns. This is only natural and was to have been anticipated for the reasons already set forth in the statement of the action of the concrete under compression in that class of members. The reinforcement is so employed that it does not come into action until the concrete has suffered material longitudinal and lateral strains. This, of course, is simply saying that the bands do not act until the lack of stiffness of the concrete enables them to perform their duties.

On the other hand, in the case of the longitudinal angle reinforcement, there can be no initial longitudinal strain except as the steel yields under direct compression. Where stiffness as well as strength are required, therefore, the longitudinal type of reinforcement has peculiarly effective advantages, to say nothing of its efficient jointing details where ends of beams or girders are carried by columns.

At first sight it seems peculiar that the stiffness of even the longitudinally reinforced columns is less than that of the plain concrete, resulting in a higher modulus of elasticity of the latter than for the concrete in the reinforced columns. It is clear, however, that in such a combination, especially where the cross-section of the steel reinforcement is but a very small per cent. of the sectional area of the concrete, the stiffness of the combined column must in all cases be less than that of the plain concrete. Whatever may be the degree of care exercised in making the reinforced member, when the column loads are applied the texture or the character of the concrete is such that the steel must necessarily carry the greater part of the initial load, so that in all stages of the loading the longitudinal strains of the steel angles are practically certain to be greater than those due to the ratio between the two moduli of elasticity. The result will be that inasmuch as the distribution of load between the two materials is not precisely what it is assumed to be, the strains within what may be termed the elastic limit of the combination will be a little greater than they should be. The condition of the concrete mixture in some cases may be such as to exaggerate greatly this result, but in all cases the apparent stiffness of the combined column must necessarily be less than that of the plain concrete. It is practically certain that this condition disturbs to some extent the computed distribution of loading between the steel and concrete, but not enough to be of material significance.

Testing Standard Equipment.

Whenever an industrial plant purchases new equipment of special design there is seldom any question about the desirability of thoroughly testing the apparatus. No large railway, for example, would consent to a radical change of motive power without exhaustive trials of selected equipment under both normal and abnormal conditions, if there were any possibility of making such tests before putting the new designs into service. Special types of locomotive valve gear, superheaters and compound cylinder arrangements are all subjected to thorough shop and road tests before duplicate units are finally purchased.

The situation is somewhat different when so-called "standard equipment" awaits acceptance. Machinery built from established and tried designs, constructed from stock patterns and shaped by tools which have turned out a long line of repeat orders, obviously needs less detailed investigation than apparatus which has still to prove its merits. There is no economy, for instance, in duplicating a long list of physical quantities in testing a motor which has performed a given service satisfactorily for a long time. The manufacturer acknowledges this point by simply testing standard machines for a few fundamental characteristics, such as temperature rise under sustained loads, commutation, etc. The purchaser who spends large sums of money on tests may well reflect on the desirability of studying details which are really non-essential to the proper performance of the machinery in regular service.

On the other hand, it is exceedingly important to determine whether or not each piece of machinery purchased meets the important contract requirements. In standard lines this can largely be ascertained by careful operating and maintenance records, carried over a prescribed period. Regular inspections in service coupled with a few tests under extra hard working conditions are likely to discover any serious faults ere the equipment has been long in use. The fitting up of testing apparatus is no light expense when elaborate determinations are desired, and in a good many cases the most economical plan in the long run is to rely upon tests for special physical quantities as made in the manufacturer's laboratory or upon his testing stand in the presence of a duly qualified representative of the purchaser. Here the facilities are usually unsurpassed for making both simple and complex tests, and most manufacturers are thoroughly willing to co-operate to all reasonable degrees with purchaser's engineers who are visiting the factory to witness tests of apparatus under contract. Tests by the purchaser are certainly always desirable on special machinery and untried products, but standard equipment often needs, aside from factory observation of tests, only careful scrutiny of regular service performance.

The Baltimore Power Station.

It is rather rarely that new power plants, by any striking innovations or originality of design, commend themselves to especial attention. In fact, stations in general are as devoid of striking features as are the full-dress habiliments of their managers and for much the same reason. The electrical arbiters of fashion, that is, the large manufacturers, bring out the styles, and the customer's only aim is to secure a good fit. If he asks for anything else he is apt to be considered a back number, or even a violent reactionary, and the salesman turns on him the cold eye of scorn. Fortunately the style is not unbecoming, by and large, and the conventional raiment will probably wear and look well until the next change of cut. Seriously, the things which distinguish one station from another, and which often make for success or failure, are details of equipment, and the station here considered seems in these respects to be admirably designed. It is situated where fuel supply is easy, has in addition large capacity for coal storage, and is on the way to an excellent water supply.

Like most turbine stations, it is very compactly arranged, and all the auxiliaries are placed where they are under the eye of the attendant and can receive prompt attention if necessary. The station itself is well lighted and ventilated and embodies the latest ideas in neat and solid construction. The thing perhaps most noticeable in the design of the equipment is the very complete steam supply and generating system. The boilers are planned, not for the operating conditions of yesterday but for those of to-morrow. Provision for 200 lb. working pressure and 200° of superheat is unusual, and bespeaks a foresight that probably will be justified. Not only can the steam and generating units be operated with complete independence, but a general application of the ring system of supply gives exceptional immunity from breakdown, so far as continuous power supply is concerned. The failure of a modern station, in fact, is a rare occurrence and is generally due when it does happen to some cause that could hardly be foreseen. Failure of cables also seems in this plant to be well guarded against, and the duplicate system of busses protects the plant against most of the contingencies to be feared. The exciting system, too often a weak point in power plants, is exceptionally well protected, an engine-driven and a motor-driven unit being provided besides which a storage battery is kept floating upon the circuit. Switches, fuses and bus-bars are enclosed in molded concrete compartments, which should make the operating parts of the system as thoroughly fireproof as one could wish. The whole switching system is controlled as usual from a single gallery overlooking the generator room.

The boilers are, as is now usual, machine-fired, and there is a complete mechanical system of coal-handling including a breaker for reducing the run-of-mine coal to uniform size for the stokers. The coal is weighed as it passes to each individual boiler and there are duplicate hot-water meters in the boiler-feed lines so that each unit can be operated under continuous test conditions. The advantages of this in securing economical operation can hardly be over-estimated. The term test conditions as against practical operation is now often used. It is to be questioned whether this comparison should be made. The former, barring hand-picked coal or the like, ought to mean and generally does mean, merely thoroughly skillful operation by a working force that knows its business; the latter is a shuffling apology for careless and incompetent management. There is not anything particularly practical to be seen in scale-lined boilers, smudgy fires, leaky valves and worn-out bearings. Testing appliances regularly in service disclose any departure from the conditions that ought to exist, and enable the responsibility for it to be located. The test of the turbo-generators for the Baltimore station, by the way, is an interesting one as showing results obtained under rather severe conditions, with a poor vacuum and no superheat to mention. For these circumstances 18.5 lb. of water per kilowatt-hour is not at all a bad performance, though it would be desirable if in this, as in every turbine test, the steam required for the auxiliaries had been considered. Very few turbine tests that have come to the notice of this journal show, including these, an economy that is in any way sensational, even at half-load; and some of them are decidedly unsatisfactory, running up around 22 to 25 lb. steam per kilowatt-hour, and that in large units. The Baltimore units make a better showing on a brake-horse-power hour basis than in electrical measure, the generator design being apparently somewhat handicapped by the high rotative speed. Taken altogether, the Baltimore station is a capital example of recent practice and shows unusual forethought and care in its details.

Depressing the Chicago River Tunnels.

The work of depressing the Chicago River tunnels, found imperatively necessary for the commercial interests of the city, and which is about to be undertaken, illustrates in a marked manner the wisdom of doing public work initially on a liberal basis wherever possible. The tunnels under the Chicago River were of course built before it was feasible to spend a large amount of money on them. In consequence of this fact they were made as shallow as the conditions of navigation at that time permitted. In fact, the tops of the tunnels were placed at such an elevation that with certain conditions of wind scarcely more than 15 or 16 ft. depth of water is afforded at the tunnel crossings. This deficient depth of water prevents the larger lake vessels from entering the Chicago River. As the commerce of the lake now exists, vessels of light draft only can navigate the Chicago River. This scant depth of 15 or 16 or 17 ft. of water is in marked contrast with the 22 ft. afforded by the drainage canal.

The most serious result of this throttled navigation, so to speak, in the Chicago River is the diminution of the Chicago lake commerce to about half its volume ten or twelve years ago. It is not a matter of surprise, therefore, that the commercial interests of the city demand relief from existing conditions. The Federal Government now requires the city to depress the tunnels so as to accommodate all classes of lake commerce. In fact, the city was required to complete this work in April of the current year, but for a number of reasons, set forth in the description of the proposed work published in this issue of The Engineering Record, the work has not yet been undertaken, although the plans are completed.

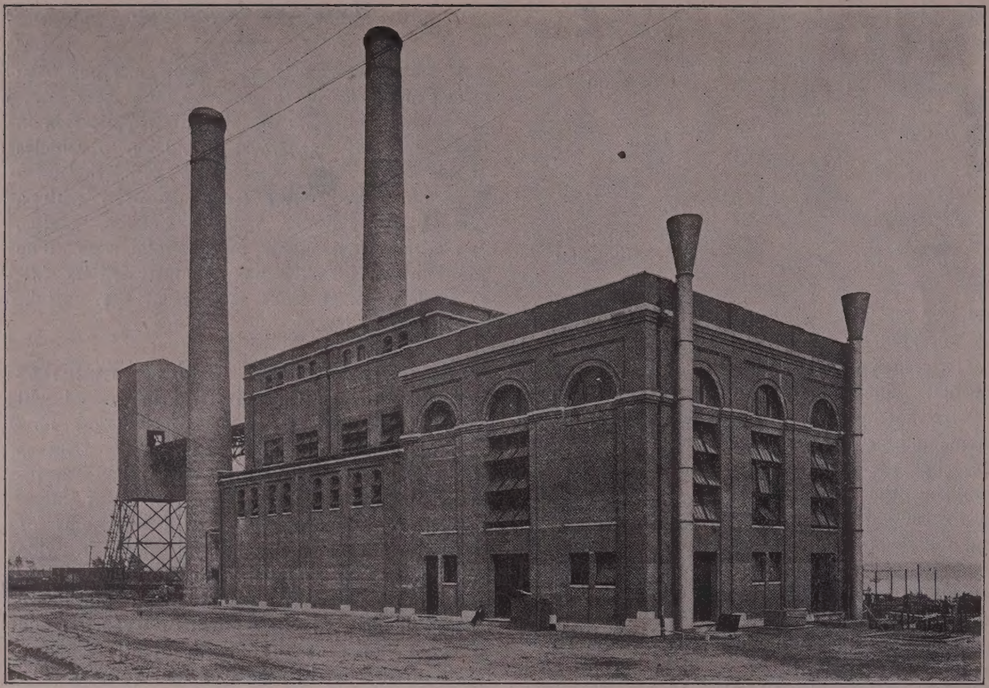
The principal features of this tunnel work are unusual. The construction of a tunnel where one has not heretofore existed is a comparatively simple matter under various methods now available, but the depression of an existing tunnel, requiring the construction of a new roof, the reconstruction of a portion of the old tunnel and the demolition of a part of the latter, is a combination almost or quite new in engineering operations. All traffic must, of course, be diverted during the work, and it is to be accommodated in Chicago by bridges over the river. A new roof intermediate in elevation between the roof and the floor of the old tunnel is first to be built and in such a way as to make the connection between the old work and the new water tight beyond a doubt. The reconstruction of that part of the tunnel below the roof, involving additional excavation below the floor of the old tunnel, does not necessarily involve special conditions, although obviously it must be conducted with care. The demolition and removal of the roof of the old tunnel is, however, a different matter. It is easy enough to remove any mass of material in the bottom of a river if there is free opportunity to use explosives, but in this case that procedure can be followed to a limited extent only. The plan of filling with clay the vacant space between the roof of the new tunnel and the roof of the old above it, will clearly give opportunity to use explosives to some extent, but the blasting will have to be done with unusual care if resort is made to it. The conditions imposed by the Federal Government are broad and liberal, as they should be, but are clearly defined as to the results to be accomplished. The character of the material in which these operations are to be conducted is fortunately to a great extent, if not entirely, favorable to success, without difficulties which would be encountered with a softer and less tenacious substance. One of the difficult conditions arises from the fact that the removal of the old roof must be completed in such a way as not to disturb the new work already completed underneath it. Any method of removal of the old roof which would produce leakage through any of the new parts must, of course, be avoided.

The advantages gained by the reconstruction of these tunnels are of great importance to the welfare of the city. At the present time the comparatively small depth of the river sometimes induces currents which cause the operation of the movable bridges to be a matter of the greatest inconvenience to all classes of traffic. Any change of the river channel which reduces these currents and enables the breaks in the street traffic to be reduced will, of course, relieve to that extent the great inconvenience now existing. It is fair to presume also that the tunnels will be distinctly improved in their reconstruction so as to enable them to serve traffic purposes more efficiently and agreeably than they have in the past. The whole work is one the progress of which will be of no little interest both to the city of Chicago and the engineering profession.

Notes and Comments.

A Motor-Driven Street Sprinkler has been placed in service by the Metropolitan Park Commission of Massachusetts, the first application in this country of mechanical propulsion to vehicles of this class. The sprinkler tank is carried on a three-ton Atlas motor truck equipped with a 24-h.-p., two-cylinder opposed gasoline engine, that carries fuel supply for 200-mile runs. The motor-driven sprinkler has demonstrated its ability to do as much work as three or four sprinklers drawn by horses.

The Evanston and Calumet Auxiliary Channels of the Chicago Drainage Canal will doubtless be placed under construction now within a reasonably short time, as the trustees of the Sanitary District of Chicago have decided to obtain the right of way for them immediately. A strip 600 ft. wide will be bought for the Evanston channel, and one 1,000 ft. wide for the Calumet channel. The former will extend from a point on Lake Michigan somewhere near Willemette, 3 miles north of Evanston and 16 miles north of the mouth of the Chicago River, to the north branch of that stream. The completion within a few months of a large new pumping station on Lawrence Ave., with intercepting sewers along the lake front leading to it, will permit the sewage of all of that portion of the north side of the city between the lake and the north branch of the river to be diverted from the lake into the latter. The sewage of the remainder of the north and of part of the west side is already discharged into that branch of the river. The flow in the north branch is extremely sluggish at all times, the sewage and storm water drainage from a closely built-up area causing such currents as exist, so that the stream is in bad condition. The cutting of the Evanston channel will relieve this noxious condition, provide water for the further dilution of the discharge from the Lawrence Ave. station and divert the sewage of Evanston and of a large urban population in towns to the north of Chicago along the lake from the latter into the river, and thence into the Drainage Canal. The Calumet channel will permit similar results to be obtained on the south side of the city. The immense sewage pumping station at Thirty-ninth St., together with an intercepting sewer to the north and one to the south along the lake and a 20-ft. conduit leading from that station to the south branch of the Chicago River (Engineering Record, Nov. 18, 1905) provide only for the diversion from the lake to the Drainage Canal of the sewage of the south side of the city as far as Seventy-ninth St. To the south of Seventy-ninth St. is a very large area within the city limits that is being built up very rapidly, and from which the sewage is now drained into the lake. Beyond the city limits along the lake are South Chicago and a number of other manufacturing towns whose sewage, directly or indirectly, reaches the lake. The Calumet channel of the Drainage Canal will cut through the most southerly part of the city and tap the Calumet River somewhere in the vicinity of South Chicago. Its completion will render possible the diversion from the lake to the canal of the sewage of all of those districts to the south of Seventy-ninth St. Although the opening of the Drainage Canal has undoubtedly had a marked beneficial effect on the character of the water supply of the city of Chicago, so long as the present sewage arrangements continue the lower end of Lake Michigan can never be considered free from liability of serious pollution and the proposed channels should certainly be constructed with all reasonable haste.



General View of the Station Before the Erection of the South Wing.

A MODEL TURBINE POWER STATION.

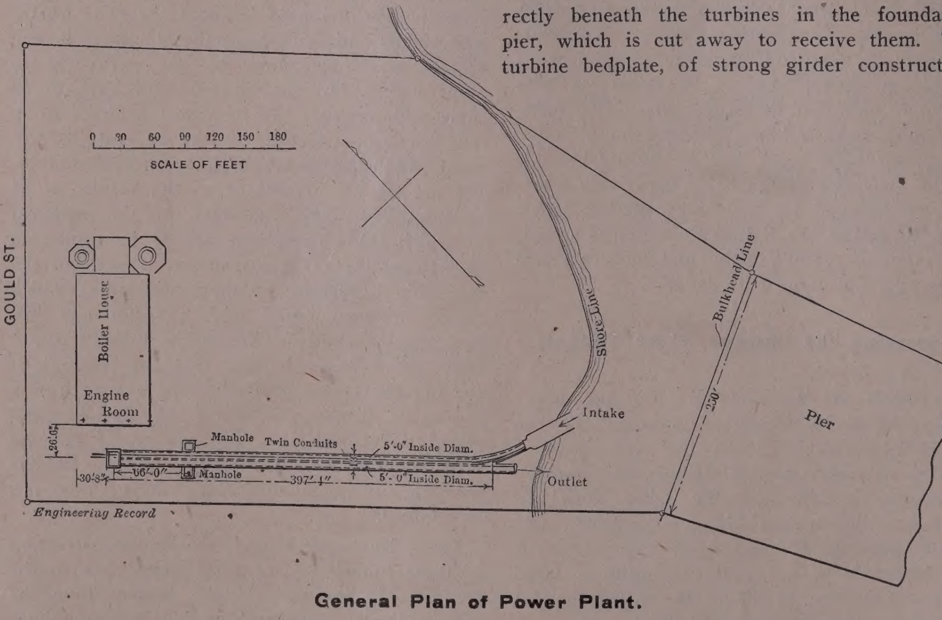
The New Turbine Plant Built by the Baltimore Electric Power Company.

In Baltimore there has recently been completed an 8,000-kw. power station designed and constructed along the most modern lines and equipped with the highest grade apparatus. In completeness of detail and provision for almost any emergency that is likely to arise, the station is well worth close study of those interested in similar undertakings. The plant has been in operation for several months with great success. With its equipment of steam turbines, high vacuum condensing apparatus, high pressure boilers, superheated steam and mechanically driven stokers and auxiliaries, it is likely to prove one of the most economical stations for its size in the country. With the starting of the Gould St. station a new electric service in Baltimore was inaugurated which is expected to go far toward extending the uses of electricity in manufacturing and residence districts.

The construction of the new power system was executed by the Eastern Electric Construction Co., a corporation financially allied with the Baltimore Electric Power Co. and the Maryland Telephone Co. The system covers the entire business and residence sections of the city, and the growth of the business has been phenomenal since the company began operations. In general, the plan of the system consists of a central power station located on the water front with high tension transmission to distributing points in the city proper. Direct current is distributed by the underground network in the central business district and alternating current for light and power in the outlying manufacturing district and residence sections.

Located in the outskirts of Baltimore on tidewater and close to the coaling docks of the Baltimore & Ohio R. R. and the Western Maryland R. R., the power station is most conveniently situated for a certain supply of fuel and condensing water. With a bunker storage capacity of 1,800 tons the station is able to operate at full load for 30 days quite independent of outside fuel supply. Further, as the condensed steam from the turbines is returned to the boilers as feed water, only a very small amount of make-up water has to be drawn from the city system. A driven well is being sunk for the auxiliary supply water. The present generating capacity of the station is 6,000 kw.

In the design and operation of the plant the unit system has been carried out in detail from the coal supply to the switchboard and also, of course, on the transmission lines. Thus, there is a separate boiler and condenser plant complete in every detail for operating each of the turbine units installed. Cross connections at various points between the two halves of the plant make possible effective inter-working, either for operative convenience or in emergencies. A ring feed main, sectioned by valves, supplies each boiler from at least three sources. A similar ring main carrying saturated steam, later reduced to 100 lb. pressure, insures a continuous supply to auxiliaries, this ring main being fed from the forward saturated steam drum of the boilers. Pipe connections between the two main steam lines, between turbine exhausts and likewise between circulating water supply lines and dry vacuum pumps, provide the necessary means for the inter-working of these portions of the plant.



General Plan of Power Plant.

In the electrical equipment duplication has also been carried out in a double set of busses and electrically operated switches, by which generator or line trouble may be generally isolated without disturbing the continuity of supply.

An extremely attractive building houses the entire plant with the exception of part of the coal-handling apparatus, shown at the rear in the accompanying photograph. In every respect it is thoroughly fireproof, having a structural steel frame, with concrete or brick walls. Reinforced concrete on the Clinton system is used in the roof, main and gallery floors. The water table, sills and building trimmings are of moulded concrete blocks which present an agreeable contrast to the red brick walls. Large window areas with balanced pivoted sash provide the necessary light and ventilation which are so often curtailed even in costly power plants. Particularly is this true of the piping deck above the boilers, where a double row of swinging windows provides ready exit for the heat radiated from boiler settings and piping. Another commendable feature is the simple but substantial iron stairs, railings and galleries which have been provided throughout the building for access between decks and to otherwise inaccessible parts of the building or valves. Arc lights illuminate the main areas, while incandescent lamps are placed in dark places, such as condenser pits and the ash gallery. All the wiring is permanently run in loricated iron conduit and junction boxes. A 40-ton, four-motor Niles traveling crane spans the engine room.

The compactness of the turbine generating units has made it possible to provide pits in the center of the turbine room between the turbines so that all auxiliaries serving the turbines are directly under the eye of the chief operator. Conforming with late practice, the condensers, which are of the surface type, are installed directly beneath the turbines in the foundation pier, which is cut away to receive them. The turbine bedplate, of strong girder construction, is reinforced at the opening by I-beams spanning the condenser pit. Each turbine unit is thus supported simply by three concrete piers under the three respective bearings, all resting on hard pan.

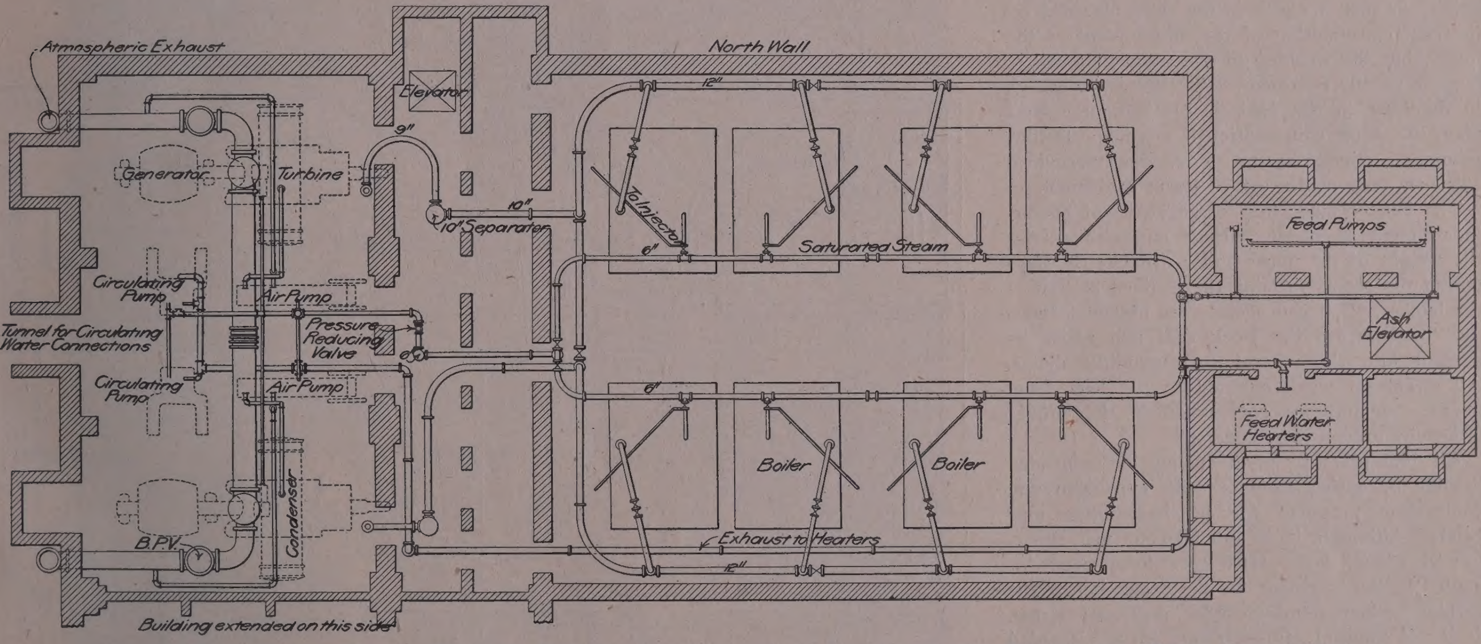
The turbines are of the Westinghouse-Parsons type with revolving-field, three-phase generators driven through flexible steel couplings. Both conform to standard Westinghouse construction. Each part of the unit can be dismantled without disturbing the other, which, with the assistance of the crane, becomes a comparatively simple matter. Independent low-head oiling systems are as usual employed for each unit, with direct-geared pump.

Each turbine has an overload capacity of easily 50 per cent. through provision of the well-known secondary admission valve which is controlled by the governor in the same manner as the primary valve. Synchronizing of the two machines when in parallel is accomplished by a small speeder mechanism operating as a detent upon the governor. Being electrically operated from the switchboard gallery, this speeder provides complete control of the generating system from the operating gallery. A safety stop of the centrifugal type at the end of each turbine shaft prevents destructive over-speeds, as it will instantly shut off steam supply when a predetermined over-speed is reached. During shop tests the turbines have shown the excellent results as indicated in the accompanying table.

EFFICIENCY TEST OF 2,000-KW. STEAM TURBINE, BALTIMORE ELECTRIC POWER CO.

	Turbine No. 153		
Approximate load.	1¼	Full.	Half.
Brake horse-power......	3408.7	2696.6	1340.8
Rated load, per cent....	120.7	106	47.5
Throttle pressure (gauge)	138.8	144.4	152.2
Superheat (deg. F.).....	11.23	9.5	2.6
Vacuum (ref. 30-in. Bar.)	26.59	27.05	27.03
Speed (r.p.m.)	1166.6	1187	1196.9
Water per hour.......	45024	35456	20948
Water per b.h.p.-hr.......	13.21	13.15	15.62
Generator efficiency* ..	95.5	95.25	92
Water per kw.-hr......	18.55	18.5	22.8

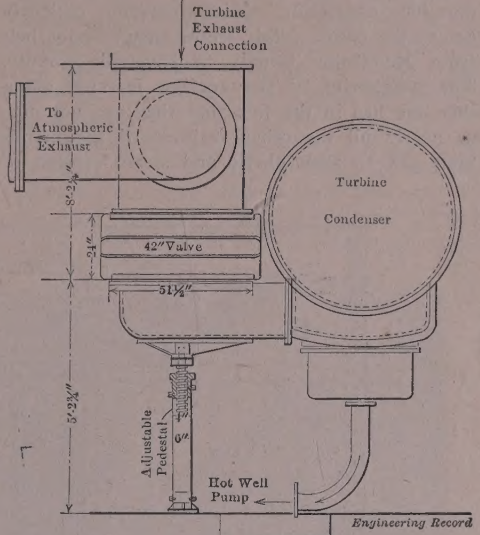
*Including iron and copper losses only. The speed variation from zero to full load was 2.4 per cent., and to overload 2.8 per cent. The safety stop acted at 11.8 per cent. excess speed above normal.



General Plan of the Station Building Showing Arrangement of Equipment and Steam and Water Connections.

Electrical control of both generating and distributing systems is entirely accomplished from one point in the first gallery, so located that the entire plant is under the eye of the operating electrician. Instead of the usual switchboard, each generator has an independent pedestal board. A third pedestal carries bus meters, this one being rotatable for greater convenience in reading the meters according to the light and position of the operator. On each machine pedestal are the machine meters, main switches, rheostat and speed regulators.

The main control of the exciter system is confined to a separate switchboard of the usual low-tension type, upon which is also mounted end-cell switch connections for the storage battery, which is at all times kept floating on the exciter bus. Two exciter generators are provided, one of which is engine-driven and the other motor-driven. Outgoing feeder panels occupy another and separate board with a complete equipment of indicating meters, electrically operated switches and time-limit relays, the latter ordinarily set at one second. Fireproof compartments built of moulded concrete blocks effectively isolate the numerous high-tension switches, fuses and busses. These blocks, which are a novelty in high-tension switchboard construction, were made by the National Hydraulic Stone Co., being moulded under heavy hydraulic presses, and form a very dense and fireproof material.



Arrangement of Turbine Connections.

Instead of being located in the basement as is usually the case, the storage battery occupies a part of the second switchboard gallery. This battery is regularly charged fully once a week (on Sundays) by a small motor-driven booster with all the end cells in circuit.

In all steam power plants as short an exhaust connection as possible is desired between engine and condenser. This is here readily obtained by placing the condenser directly beneath and at right angles to the turbine. As the counter-turbine type of Alberger condenser usually takes steam at the bottom, a special exhaust nozzle was designed for this plant, which furnishes room in the exhaust downtake not only for a gate valve, but also a cross-connecting pipe between the two equipments, so as to provide, as above noted, inter-working between the condenser and turbine equipments in case of necessity. Both these large gate valves, as well as that in the cross-connection pipe, are motor-driven and controlled from small switchboards on the main floor near the turbine throttles.

The condenser capacity is sufficient so that if one is out of commission the other can readily handle the steam from both turbine units. Under individual working the rating is 4 sq. ft. per kilowatt or working together 2 sq. ft. per kilowatt. Very high vacuum is obtained when running independently, over 29 in. at the present time. Standard two-stage rotative dry vacuum pumps remove air from the condenser shell, and a pair of centrifugal pumps driven by vertical simple engines supply cooling water, which is led to and from the cold and hot wells respectively by reinforced concrete ducts extending down to the water front. These were illustrated in The Engineering Record of Sept. 30, 1905. To prevent the return of the hot discharge water, a wing wall has been built out into the harbor for a distance of several hundred feet.

As there is a lift of 8 or 10 ft. at the pumps and 12 ft. at the condenser inlet, the circulating system has to be primed in starting. This is very easily accomplished by a pipe loop carried to the height of 35 ft. inside one of the building columns, which establishes connection between the top of the condenser shell and water heads respectively. By first starting the dry air pumps the vacuum obtained is sufficient to pull the circulating water through the pump and into the condenser. The syphon effect is then established and the circulating pumps simply work against friction head. This method has many advantages over that frequently employed of connecting the pipe loop directly between the air pump and circulating water line. In this case it frequently occurs that a dangerous quantity of water is carried over the loop in the form of spray to the air pump, whereas with the condenser connection the condenser operates as a separator of great volume and prevents such action.

Arranged in two rows of two batteries each and in every respect symmetrical, the boiler room presents a very pleasing appearance, particularly on account of its being well lighted from above. As before stated, the two sections of the plant are quite independent and yet inter-operative. The designer has not confined himself to usual operating conditions, but has equipped the plant for a pressure of 200 lb. and a superheat up to 200° Fahr. To furnish this superheat the water-heating surface of the boilers is augmented about one-third by a range of internal superheater tubes forming the second pass in the Stirling boiler. These may be flooded at any time, by which the evaporative capacity is somewhat increased.

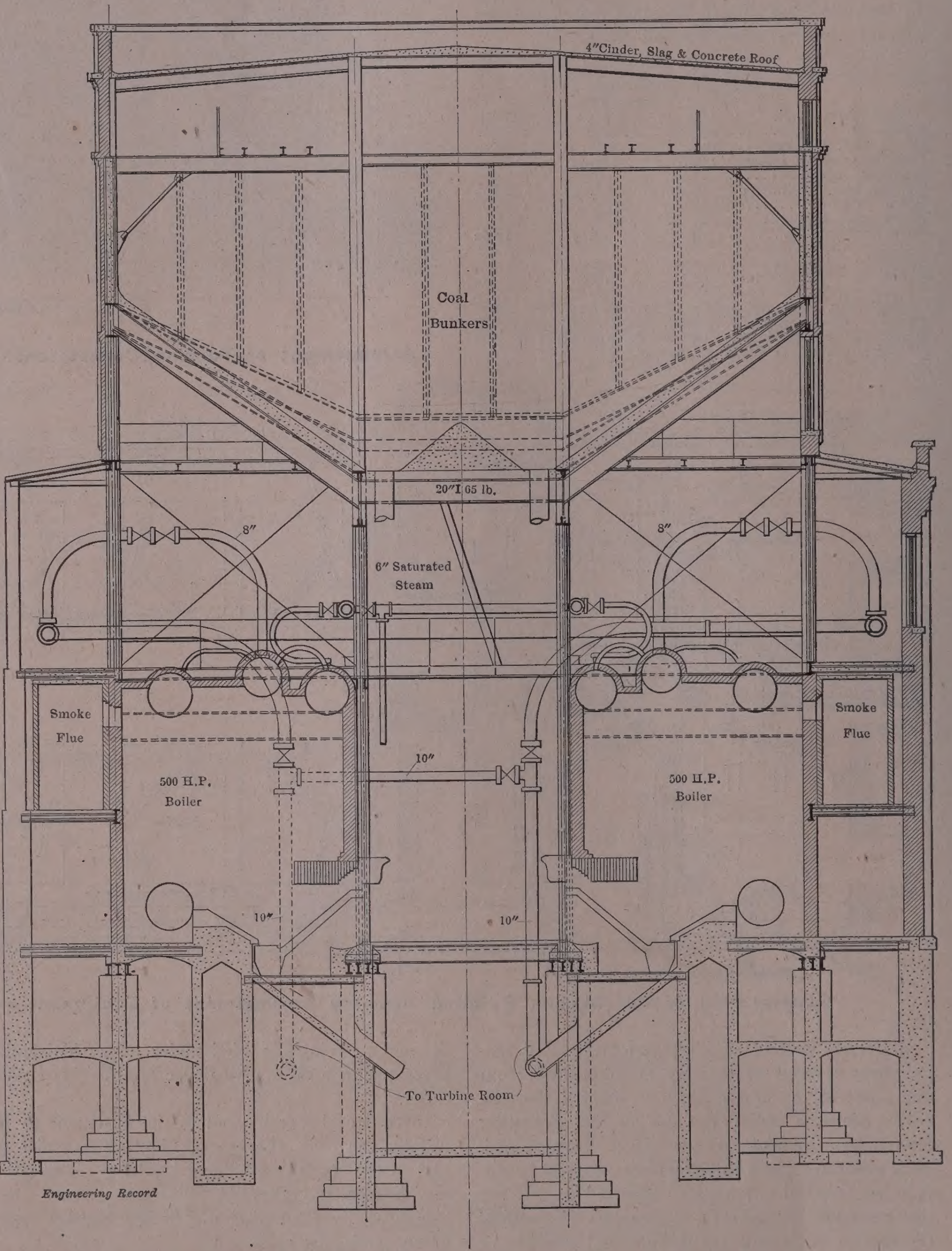
Conspicuous among the several features of the boiler room is the mechanical handling and stoking of fuel. Face couplings on the driving shaft of the Roney mechanical stokers provide for driving an entire row by one engine, as is done in normal operation. Each battery, however, has an extra driving engine for greater security against stoppages. The stokers deliver the ashes to concrete ash pits beneath, which in turn empty into dump cars running along the boiler room subway to the end of the building. At this point an electric hoist elevates the ashes to the ground floor, where they are at present wheeled out by hand for the purpose of reclaiming some low ground in the vicinity of the power house.

The coal-handling equipment ordinarily receives run-of-mine coal from hopper cars on the siding. Crushing this to a uniform size, it elevates the coal by means of a skip hoist into a tower, dumping into a hopper which in turn discharges into delivery cars. These are operated on a motor-driven cable railway. After each car is check-weighed, it is run into the storage house and automatically dumped at any desired point. About 35 tons per hour can be handled by this method. Dropping from the bunker into the stoker chutes, the coal is again weighed as it is drawn out for each individual boiler, so that a check is not only obtained on the coal consumption of the entire plant at the tower, but the working of the individual boilers is more readily recorded. With hot water meters in duplicate in the feed lines a running check upon the water consumption is possible. It thus becomes a simple matter to conduct periodical efficiency tests on the entire steam equipment.

The bunker-supporting structure is, of course, independent of boiler settings and also carries the weight of the upper boiler drums. By staggering the beams forming the inclined bottom of the bunker, V-shaped pockets are obtained, tending to segregate the stock coal and assist its descent into the several corresponding chutes. All structural work exposed to the heat from possible spontaneous combustion in the bunker is heavily protected by concrete.

All high-pressure steam piping is suspended flexibly by spring handers, with expansion and contraction provided for by long-radius pipe bends. Although it is intended to use superheated steam, large separators have been installed in the basement for the protection of the turbines when running under saturated steam. It is not unusual for separators to be discarded in plants using superheated steam. The practice is, however, to be deplored, and will sooner or later lead to trouble from occasional failures of superheat. The entire live-steam system is drained by a Holly steam-loop system. Draft is furnished by two independent stacks, the smaller one serving a single row of boilers, the larger the remaining row. The latter, however, is designed to serve an additional row of boilers when such additions to the plant shall be deemed necessary. Damper regulators near the stack intakes assist firemen in maintaining uniform pressure.

The station was built from the plans of Mr. James B. Scott, the company's designing and consulting engineer.



Cross Section of Boiler Room, Baltimore Electric Power Co.

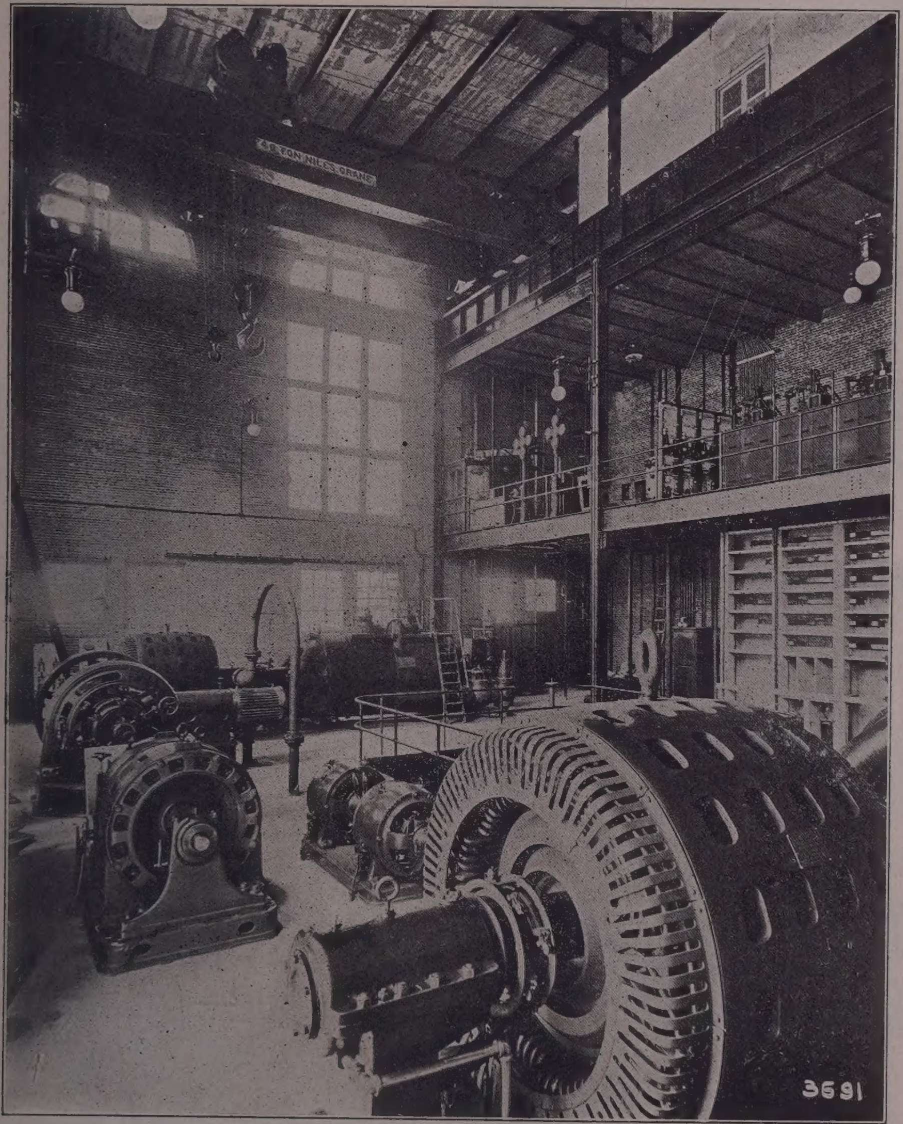
The Prevention of Electrolysis of the condenser tubes in the Long Island R. R. power plant by the methods described in this journal on June 16, has been very successful. Mr. W. W. Churchill stated at the recent meeting of the American Association for the Advancement of Science that during fourteen months of operation, the only indication of electrolysis was the pitting of about ten tubes.

Report of the State Commission on the California Earthquake.

Prof. A. C. Lawson, chairman; Prof. A. O. Leuschner, secretary.

One of the remarkable features of the Coast Ranges of California is a line of peculiar geomorphic expression which extends obliquely across the entire width of the mountainous belt from Mendocino County to Riverside County. The peculiarity of the surface features along this line lies in the fact that they are not due, as nearly all the other features of the mountains are, to atmospheric and steam erosion of the uplifted mass which constitutes the mountains, but have been formed by a dislocation of the earth's crust, or rather a series of such dislocations, in time past, with a differential movement of the parts on either side of the plane of rupture. In general this line follows a system of long, narrow valleys, or where it passes through wide valleys it lies close to the base of the confining hills, and these have a very straight trend; in some places, however, it passes over mountain ridges, usually, at the divide separating the ends of two valleys; it even in some cases goes over a spur or shoulder of a mountain. Along this line are very commonly found abrupt changes in the normal slope of the valley sides giving rise to what are technically known as scarps. These scarps have the appearance of low, precipitous walls which have been usually softened and rounded somewhat by the action of the weather. Small basins or ponds, many having no outlet, and some containing saline water, are of fairly frequent occurrence and they usually lie at the base of the small scarps. Trough-like depressions also occur bounded on both sides by scarps. These troughs and basins can only be explained as due to an actual subsidence of the ground or to an uplift of the ground on one side or the other, or on both sides. The scarps similarly can only be ascribed to a rupture of the earth with a relative vertical displacement along the rupture plane. Frequently small knolls or sharp little ridges are found to characterize this line and these are bounded on one side by a softened scarp and separated from the normal slope of the valley side by a line of depression. In many cases these features have been so modified and toned down by atmospheric attack that only the expert eye can recognize their abnormal character; but where their line traverses the more desert parts of the Coast

Range, as for example in the Carissa Plains, they are well known to the people of the country and the aggregate of the features is commonly referred to as the "earthquake crack."



General View of the Turbine Room, Baltimore Electric Power Co.

The exciter units and battery booster are in the foreground, and the auxiliary storage battery room is on the upper floor or crane deck.

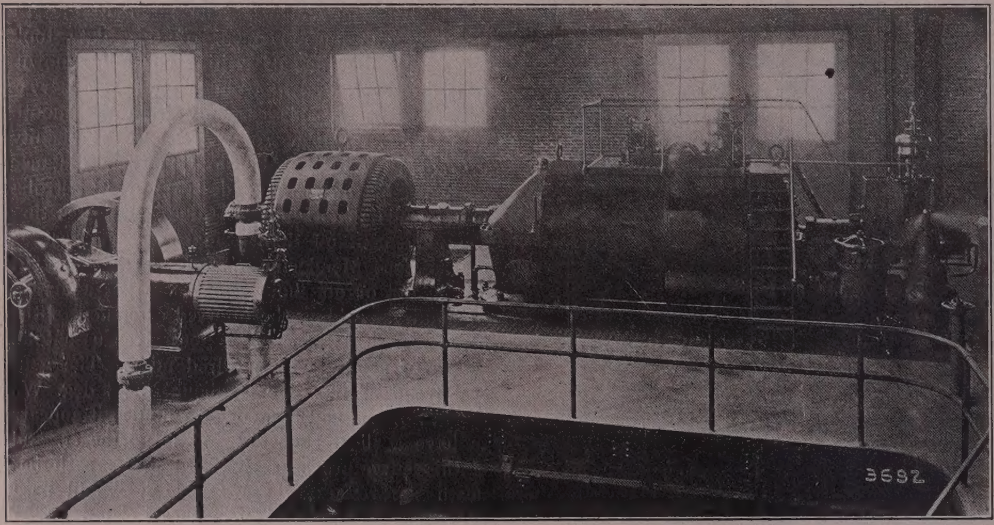
This line begins on the north at the mouth of Alder Creek near Point Arena and extends southeasterly nearly parallel with the coast line to a point about two miles below Fort Ross, a distance of forty-three miles. Here it passes outside of the shore line and is again met with at the point where Bodega Head joins the mainland. Thence it appears to continue southward through Tomals Bay and Bolinas Lagoon. Beyond Bolinas Lagoon it passes outside of the Golden Gate and enters the shore again at Mussel Rock, eight miles south of the Cliff House. From this point it is traceable continuously along the valley line occupied by San Andreas and Crystal Springs Lakes, past Woodside and Portola, over a saddle back of Black Mountain, thence along Stevens Creek Cañon, passing to the southwest of Table Mountain and Congress Springs to the vicinity of Wrights, on the narrow-gauge railway between San José and Santa Cruz. From Wrights it continues on in the same course through the Santa Cruz Mountains to the point where the Southern Pacific Railway crosses the Pajaro River near Chittenden. From the crossing of the Pajaro the line extends up the valley of the San Benito River, across the eastern portion of Monterey County, and thence follows the northeastern side of the valley of the San Juan River and the Carissa Plains to the vicinity of Mount Pinos, in Ventura County. The line thus traced from Point Arena to Mount Pinos has a length of 375 miles, is remarkably straight, and cuts obliquely across the entire breadth of the Coast Ranges. To the south of Mount Pinos the line either bends to the eastward following the general curvature of the ranges or is paralleled by a similar line offset from it en echelon; for similar features are reported at the Tejon Pass and traceable thence though less continuously across the Mojave Desert to Cajon Pass and beyond this to San Jacinto and the southeast border of the Colorado Desert. The probability is that there are two such lines, and that the main line traced from Point Arena to Mount Pinos is continued with the same general straight trend past San Fernando and along the base of the remarkably even fault scarp at the foot of which lies Lake Elsinore. But, leaving the southern extension of the line out of consideration as somewhat debatable, we have a very remarkable physiographic line extending from Point Arena to Mount Pinos which affords every evidence of having been in past time a rift, or line of dislocation, of the earth's crust and of recurrent differential movement along the plane of rupture. The movements which have taken place along this line extend far back into the Quaternary period, as indicated by the major, well degraded fault scarps and their associated valleys; but they have also occurred in quite recent times, as is indicated by the minor and still undegraded scarps. Probably every movement on this line produced an earthquake, the severity of which was proportionate to the amount of movement.

The cause of these movements in general terms is that stresses are generated in the earth's crust which accumulate till they exceed the strength of the rocks composing the crust and they find a relief in a sudden rupture. This establishes the plane of dislocation in the first instance, and in future movements the stresses have only to accumulate to the point of overcoming the friction on that plane and any cementation that may have been effected in the intervals between movements.

The earthquake of April 18, 1906, was due to one of these movements. The extent of the rift upon which the movement of that date took place is at the time of writing not fully known. It is, however, known from direct field observations that it extends certainly from the mouth of Alder Creek near Point Arena to the vicinity of San Juan in San Benito County, a distance of about 185 miles. The destruction at Petrolia and Ferndale in Humboldt County indicates that the movement on the rift extended at least as far as Cape Mendocino, though whether the rift lies inland or off shore remains as yet a matter of inquiry. Adding the inferred extension of the movement to its observed extent gives us a total length of about three hundred miles. The general trend of this line is about N. 35 deg. W., but in Sonoma and Mendocino counties it appears to have a slight concavity to the northeast, and if this curvature be maintained in its path beneath the waters of the Pacific it would pass very close to and possibly inside of Capes Gordo and Mendocino. Along the 185 miles of this rift where movement has actually been observed the displacement has been chiefly horizontal on a nearly vertical plane, and the country to the southwest of the rift has moved northwesterly relatively to the country on the northeast of the rift. By this it is not intended to imply that the northeast side was passive and the southwest side active in the movement. Most probably the two sides moved in opposite directions. The evidence of the rupture and of the differential movement along the line of rift is very clear and unequivocal. The surface soil presents a continuous furrow generally several feet wide with transverse cracks which show very plainly the effort of tortion within the zone of the movement. All fences, roads, stream courses, pipe lines, dams, conduits and property lines which cross the rift are dislocated. The amount of dislocation varies. In several instances observed it does not exceed 6 ft. A more common measurement is 8 to 10 ft. In some cases as much as 15 or 16 ft. of horizontal displacement has been observed, while in one case a roadway was found to have been differentially moved 20 ft. Probably the mean value for the amount of horizontal displacement along the rift line is about 10 ft. and the variations from this are due to local causes such as drag of the mantle of soil upon the rocks, or the excessive movement of soft incoherent deposits. Besides this general horizontal displacement of about 10 ft. there is observable in Sonoma and Mendocino counties a differential vertical movement not exceeding 4 ft., so far as at present known, whereby the southwest side of the rift was raised relatively to the northeast side, so as to present a low scarp facing the northeast. This vertical movement diminishes to the southeast along the rift line and in San Mateo County is scarcely if at all observable. Still farther south there are suggestions that this movement may have been in the reverse direction, but this needs further field study.

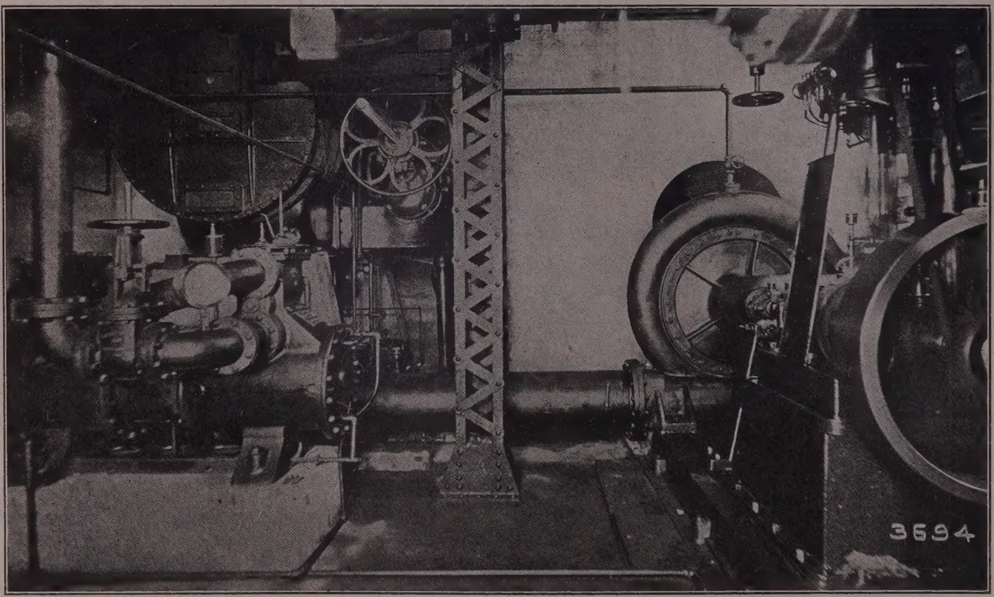
As a consequence of the movement it is probable that the latitudes and longitudes of all points in the Coast Ranges have been permanently changed a few feet, and that the stations occupied by the Coast and Geodetic Survey in their triangulation work have been changed in position. It is hoped that a reoccupation of some of these stations by the Coast and Geodetic Survey may contribute data to the final estimate of the amount of movement.

The great length of the rift upon which movement has occurred makes this earthquake unique. Such length implies great depth of rupture, and the study of the question of depth will, it is believed, contribute much to current geophysical conceptions.



View in Turbine Room, Baltimore Electric Power Co.

The time of the beginning of the earthquake as recorded in the Observatory at Berkeley was 5 hr. 12 min. 6 sec. A. M., Pacific standard time. The end of the shock was 5 hr. 13 min. 11 sec. A. M., the duration being 1 min. 5 sec. Within an hour of the main shock twelve minor shocks were observed by Mr. S. Albrecht, of the Observatory, and their time accurately noted. Before 6 hr. 52 min. P. M. of the same day thirty-one shocks were noted in addition to the main disturbance. These minor shocks continued for many days after April 18, and in this respect the earthquake accords in behavior with other notable earthquakes in the past. The minor shocks which succeed the main one are interpreted generally as due to subordinate adjustments of the earth's crust in the tendency to reach equilibrium after the chief movement.



View in the Condenser Basement, Power Plant of Baltimore Electric Power Co.

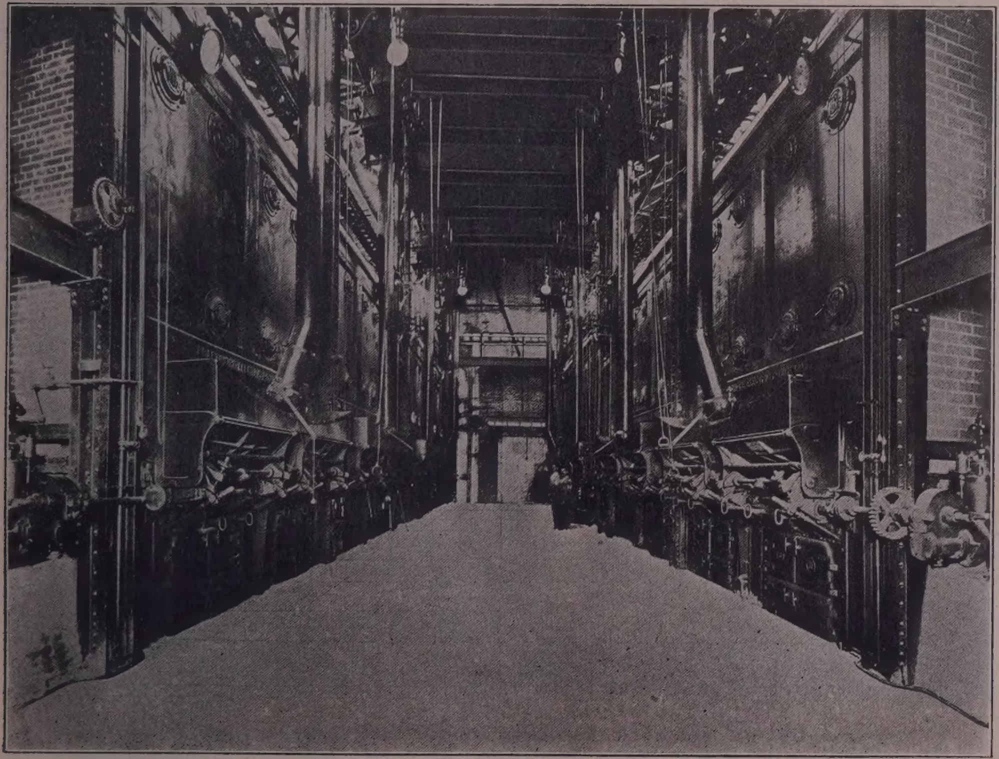
The circulating pump is on the right. The motor-driven control valve and the condenser shell are in the background.

The collection of time records necessarily proceeds slowly. The purpose of the coseismal curves based upon these records is in general two-fold. In ordinary earthquakes it is one of the means of locating the seat of the disturbance when there is no surface manifestation of the rupture in the earth's crust. In the present instance, however, the rupture has declared itself in an unmistakable rift observable at the surface, and coseismals are, therefore, unnecessary for the determination of this important factor in the general problem, so far at least as regards the main disturbance. It is probable, however, that so radical a change in the equilibrium of the stresses of the earth's crust would induce secondary ruptures and consequently secondary earthquakes closely associated with the chief shock. The careful plotting of the time records may, therefore, be useful in revealing the location of these secondary disturbances, such for example as the one which affected Southern California on the afternoon of April 18. The second purpose of securing time records is the determination of the velocity of propagation of the earth wave; and the data for this which are likely to be most serviceable are the records obtained at various quite distant seismographic stations.

The destructive effects of the earthquake are in the main distributed with reference to the line of rift. The exact limits of the area of destruction have not yet been mapped, but it is known to extend out about twenty-five or possibly thirty miles on either side of the rift. On the southwest side the greater part of this area to the north of the Golden Gate lies in the Pacific. This area extends from Eureka, in Humboldt County, to the southern extremity of Fresno County, a distance of about four hundred miles.

Beyond this area of destructive shock the earthquake was felt in its milder manifestations over a wide territory. Our reports to date show that it was felt in Oregon as far north as Coos Bay and on the south as far as Los Angeles. To the east it was felt over the greater part of Middle California and Eastern Nevada, particularly along the eastern flank of the Sierra Nevada. It was felt at Lovelocks, and we have unconfirmed reports of its having been felt at Winnemucca. Far beyond the region within which it was apparent to the senses, however, the earth wave was propagated both through the earth and around its periphery; and some of the most valuable and most accurate records of the disturbance which we have are those which were registered at such distant seismographic stations as Washington, D. C.; Sitka, Alaska; Potsdam, Germany, and Tokyo, Japan.

Within the area of destructive effects approximately four hundred by fifty miles in extent the intensity varied greatly. There was a maximum immediately on the rift line. Water pipes, conduits and bridges crossing this line were rent asunder. Trees were uprooted and thrown to the ground in large numbers. Some trees were snapped off, leaving their stumps standing, and others were split from the roots up. Buildings and other structures were in general violently thrown and otherwise wrecked, though some escaped with but slight damage. Fissures opened in the earth and closed again, and in one case reported a cow was engulfed. A second line of maximum destruction lies along the floor of the valley system of which the Bay of San Francisco is the most notable feature, and particularly in the Santa Rosa and Santa Clara valleys. Santa Rosa, situated twenty miles from the rift, was the most severely shaken town in the State and suffered the greatest disaster relatively to its population and extent. Healdsburg suffered to a nearly similar degree. San José, situated thirteen miles, and Agnews, about twelve miles from the rift, are next in the order of severity. Stanford University, seven miles from the rift, is probably to be placed in the same category. All of these places are situated on the valley floor, and are underlain to a considerable depth by loose or but slightly coherent geological formations, and their position strongly suggests that the earth waves as propagated by such formations are much more destructive than the waves which are propagated by the firmer and highly elastic rocks of the adjoining hill lands. This suggestion is supported by a consideration of the destructive effects exhibited by towns and single buildings along the same valley line which are situated wholly or partly on rock. Petaluma and San Rafael, though nearer the rift than Santa Rosa, suffered notably less, and they are for the most part on, or close to, the rocky surface. The portions of Berkeley and Oakland which are situated on the alluvial slope suffered more than the foothills, where the buildings are founded on rock. The same suggestion is further supported from a consideration of the zone of maximum destructive effect on the southwest side of the rift. This zone lies in the Salinas Valley. The intensity of destructive action at Salinas was about the same as at San José, and the town is situated on the flood plain deposits of the Salinas River. Along the banks of the Salinas River and extending from Salinas to the vicinity of Gonzales, so far as our reports at present show, the bottom lands were more severely ruptured, fissured and otherwise deformed than in any other portion of the State. The Spreckels sugar mill, situated on the banks of the river, suffered more severely probably than any other steel structure in the State. Santa Cruz, on the other hand, which is on the same side of the rift, and at the same distance from it, but which is built on rock for the most part, suffered much less damage. In the northern counties along the coast the most severe effects were felt at Ferndale, on the south margin of the flood plain of the Eel River, and at Petrolia, on the bottom land of the Mattole. Fort Bragg was severely shaken with very destructive effects, but our reports do not yet indicate the character of the ground upon which it is situated.



General View of the Boiler Room, Baltimore Electric Power Co.

In the facts which have been cited we seem to have warrant for a generalization as to the excessively destructive effect of the earth wave as transmitted by the little coherent formations of the valley bottoms. But it must be borne in mind that by far the greater number of structures subject to destructive shock are situated in the valley lands and that there has not yet been time for a detailed comparison of the effects in the valleys with those in the hills, where the buildings are founded on firm rock except in a few notable instances.

The most instructive of these instances is the city of San Francisco, and the facts observed there are entirely in harmony with the generalization above outlined. In the city of San Francisco we may recognize for preliminary purposes four types of ground: (1) The rocky hill slopes; (2) the valleys between the spurs of the hills which have been filled in slowly by natural processes; (3) the sand dunes; (4) the artificially filled land on the fringe of the city. Throughout the city we have a graded scale of intensity of destructive effects which corresponds closely to this classification of the ground. The most violent destruction of buildings, as everybody knows, was on the made ground. This ground seems to have behaved during the earthquake very much in the same way as jelly in a bowl, or as a semi-liquid material in a tank. The earth waves which pass through the highly elastic rocks swiftly with a small amplitude seem in this material to have been transformed into slow undulations of great amplitude which were excessively destructive. The filled in material and the swampy foundation upon which it rests behaved, in other words, as a mass superimposed upon the earth's surface, rather than as a part of the elastic crust itself. In a less degree the same thing is true of the sand dune areas, where the ground was frequently deformed and fissured. In still less degree the naturally filled valleys between the hill spurs were susceptible to this kind of movement, and the destruction of buildings was correspondingly less, but still severe, depending very largely on the character of the buildings, the integrity of their construction, etc. In portions of these valleys, however, the original surface of the ground has been modified by grading and filling, and on the filled areas the destruction was more thorough than elsewhere in the same valley tracts. On the rocky slopes and ridge tops, where, for the most part, the vibration communicated to buildings was that of the elastic underlying rocks, the destruction was at a minimum. On some of the hills chimneys fell very generally and walls were cracked; on others even the chimneys withstood the shock.

While this correlation of intensity of destructive effect appears to hold as a generalization, there are well known exceptions which find their explanation in the strength of the structures. Modern class A steel structures with deep foundations appear to have been relatively passive, while the made ground in their immediate vicinity was profoundly disturbed. Thoroughly bonded and well cemented brick structures, on similarly deep and solid foundations, seem to have been equally competent to withstand the shock, except for occasional pier-like walls not well tied to the rest of the building. The weak points in wooden frame structures were in general the faulty underpinning and lack of bracing, and chimneys entirely unadapted to resist such shocks. With these faults corrected, frame buildings of honest construction would suffer little damage beyond cracking of plaster in such a shock as the 18th of April, save on the made ground, where deep foundations and large mass appear to be essential for the necessary degree of passivity.

Pipe lines and bridges crossing the rift line present a peculiar, if not quite unique, engineering problem which will doubtless be solved in the near future. Pipe lines on low, swampy grounds or in made ground are in much greater danger of destruction from earthquake shocks than those on high ground underlaid by rock, except in the immediate vicinity of the rift, where nothing could be constructed which would withstand the violence of the earth movement.

One of the lessons of the earthquake which seems peculiarly impressive is the necessity for studying carefully the site of proposed costly public buildings where large numbers of people are likely to be congregated. In so far as possible such sites should be selected on slopes upon which sound rock foundation can be reached. It is probably in large measure due to the fact of their having such a rock foundation that the buildings of the State University, at Berkeley, escaped practically uninjured. The construction of such buildings as our public schools demands the most earnest attention of the people and of the authorities charged with their construction. A great many of our schools proved to be of flimsy construction and ill adapted to meet the emergency of an earthquake shock of even less severity than that of April 18.

The commission in presenting this brief report has had in mind the demand on the part of the people of the State and of the world at large for reliable information as to the essential facts of the earthquake. It has, therefore, not presumed to engage in any discussion of the more abstruse geological questions which the event naturally raises. It leaves such discussion for a more exhaustive report which can only be prepared after the campaign of data collection is complete, and that may be some months hence.

Testing Steel at extremely low temperatures was done during the past year at the Watertown Arsenal in Massachusetts. After the specimens had been placed in a tensile testing machine they were cooled in a bath of liquid air and the resulting contraction of the metal measured by an extensometer, the increase of stress being recorded on the weighing bar of the testing machine. The steels tested varied in quality from 0.16 to 1.09 per cent. carbon, but the amount of contraction in the different specimens was substantially the same, the range being from 0.00177 to 0.00191 in. per linear inch of the specimen. An initial stress of 4,000 lb. per square inch on one of the bars was increased to 26,800 lb. per square inch by the contraction of the specimen due to the cooling by the liquid air bath; the elastic limit of this steel was 80,000 lb. per square inch, with an elongation of 10.7 per cent. at the low temperature of the liquid air. A similar specimen tested at a room temperature of 76° Fahr. showed an elastic limit of 52,800 lb. per square inch, an elongation of 29.3 per cent., the effect of the very low temperature being to increase the elastic limit of the steel 51 per cent., while the ultimate strength of the steel was raised to 97,600 lb. per square inch, or 35 per cent. above the ultimate strength at ordinary temperatures. The results of these experiments are similar to those that have been obtained by numerous other experimenters, who have investigated the properties of steel under the same conditions, in that it is shown that a great increase is produced in the tensile strength of steel at low temperatures, with a corresponding decrease in ductility.

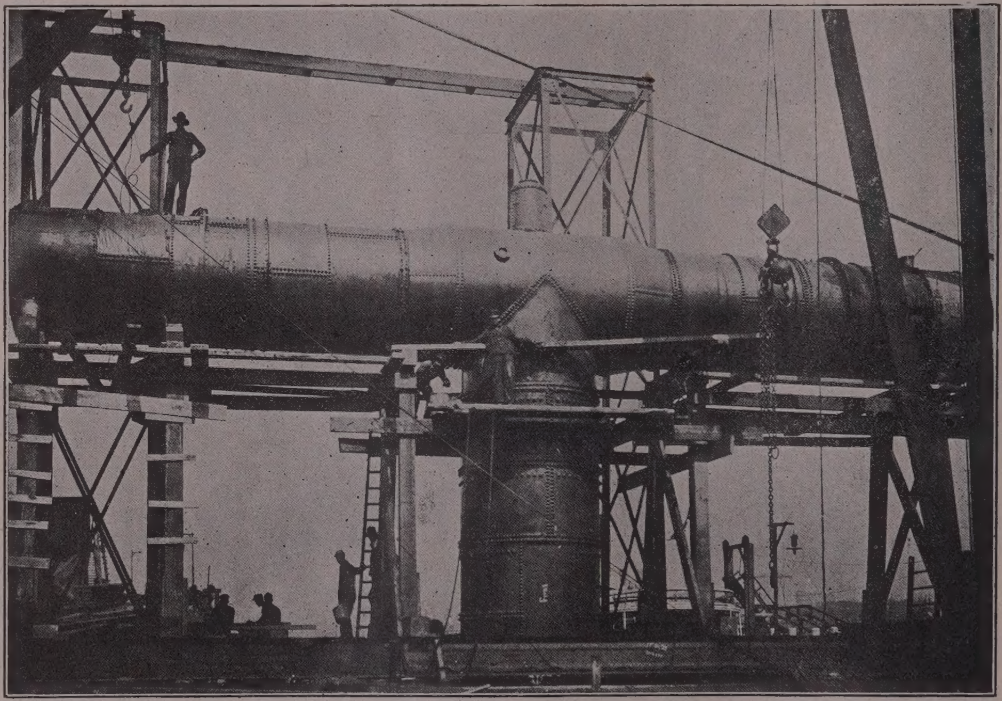
The East River Tunnels for the New York City Terminus of the Pennsylvania and Long Island Railroads.—II.

The East River division of the Pennsylvania, New York and Long Island R. R., includes four parallel single-track cast-iron lined tubular tunnels under the East River which have an aggregate length of about 3,900 ft. They are located in two pairs, each of which intersects the bottom of a river shaft, from 74 to 88 ft. deep, two near First Ave., New York, between 32d and 34th Sts., and two near Front St., Long Island City, between Flushing St. and Borden Ave. The general features of the work, its magnitude and an outline of its present condition and the methods of executing it were briefly described in The Engineering Record for July 7. This article was the first which had been authorized by the engineers and contractors since the award of the contracts in 1904. It summarized the most important information relative to this work and in connection with the articles previously published in these columns illustrating the contract drawings and specifications presents a comprehensive outline of this portion of the great improvement now under way which is in many respects unprecedented both as regards magnitude, cost, and the difficulties encountered.

In a work involving so great an outlay, such large quantities of very difficult excavation, and so many features of unique construction and advanced application of scientific and mechanical appliances, there are many very novel and important features not only in the details of the permanent structure, but in the methods of operation employed, the safeguards for life and property, and the special plant installed. As this work is much larger, more costly and more difficult than any other similar engineering construction, the description of all the special features would be of great interest and would, in many respects, epitomize the latest developments in difficult shaft and tunnel work. Such treatment cannot be completely afforded to it here, but many of the important features of the work are covered by some official drawings and photographs and by a large amount of data secured by the staff of The Engineering Record. From these data a description was published in our columns last week exclusively illustrating the remarkable work on the steel and concrete caissons for the river shaft, a subject not previously described or illustrated in any technical publication. The present article describes the location and equipment of the surface yards on both sides of the river, and describes that portion which is above ground of the immense amount of plant installed by the contractors for executing the work.

At the New York end of the tunnels the land available for the contractors' use is located adjacent to the shafts on both sides of Thirty-third St., and is divided by a partition running through the centers of the shafts and separating the area allotted to the contractor for the river tunnels from that allotted to the contractor for the adjacent land tunnels. S. Pearson & Sons, Inc., the contractors for the river tunnels, have a yard about 380 x 230 ft. in extreme dimensions exclusive of the viaduct and pier which together extend nearly 400 ft. from the main yards. Except the portions used for storage, the ground is almost entirely covered by a number of buildings for the power plant and the different shops, offices, warehouses and other structures located as indicated in the accompanying plan, and by the trestles for the viaducts and overhead platforms on which all of the tracks are run at a sufficient level to carry part of them over the street cars in Thirty-third St. This arrangement involves a large amount of trestle work and provides an area of many thousand square feet of elevated platforms at two levels which are used for tracks, storage and various purposes.

The pier at the foot of East Thirty-third St. is divided into two portions by a longitudinal line, one side of which with the corresponding slip is occupied by the contractor for the land tunnels. The other side is occupied by S. Pearson & Sons, Inc., and is long enough to simultaneously accommodate two large scows alongside. At the end of the pier is located a stiff-leg derrick with a 40-ft. boom, which is used for unloading coal with a bucket as well as for handling the segments of the cast-iron tunnel shell and other materials delivered by boat. Coal is delivered by the derrick to dump cars running to the power house on a standard-gauge track elevated about 25 ft. above the surface of the ground. These cars dump into wooden storage bins of about 2,000 tons capacity from which the coal is shoveled by hand to the boilers. The coal track occupies the upper platform of a two-story viaduct which it shares with a standard-gauge track for the five-ton locomotive derricks and two 30-in. gauge tracks for spoil cars.



Double Air Lock for Long Island City Tunnel Shaft.

The crane track and the narrow-gauge tracks connect by a system of switches and cross-overs with the concrete plant and with both shafts, thus providing for complete distribution of materials and serving all parts of the yard. Muck is hoisted from the tunnel in cars of about 16 cu. ft. capacity that are raised by cage elevators in each of the two chambers into which each main shaft is divided. They are brought to the upper level and run on short tracks to tipples discharging them to storage bins under the floor. From these bins the muck is delivered to 4-yd. wood-lined steel side-dump cars drawn by mules on a standard-gauge track about 10 ft. below the upper track, to the end of the pier where they are dumped over a cantilever apron into scows alongside which convey the material to Greenville, N. J., where it is used by the railroad company for fill.

The tipples are simple steel frames with tracks to receive the cars. The latter are locked to them and they are revolved about their horizontal axes, dumping the contents of the cars and returning them to their original positions. One tipple is fixed and two are movable, thus providing abundantly for the rapid disposition of a large amount of muck. The bin into which the tunnel cars discharge, is a chamber occupying the full width of the trestle and having a horizontal floor about 4 ft. below the upper platform and just clear of the tops of the 4-yd. cars which are filled through openings in it. These openings were originally intended to be closed with movable gates, but it is found more convenient to leave them constantly open so that the bin does not now serve for storage, and all the muck passes directly through it to cars which are constantly waiting.

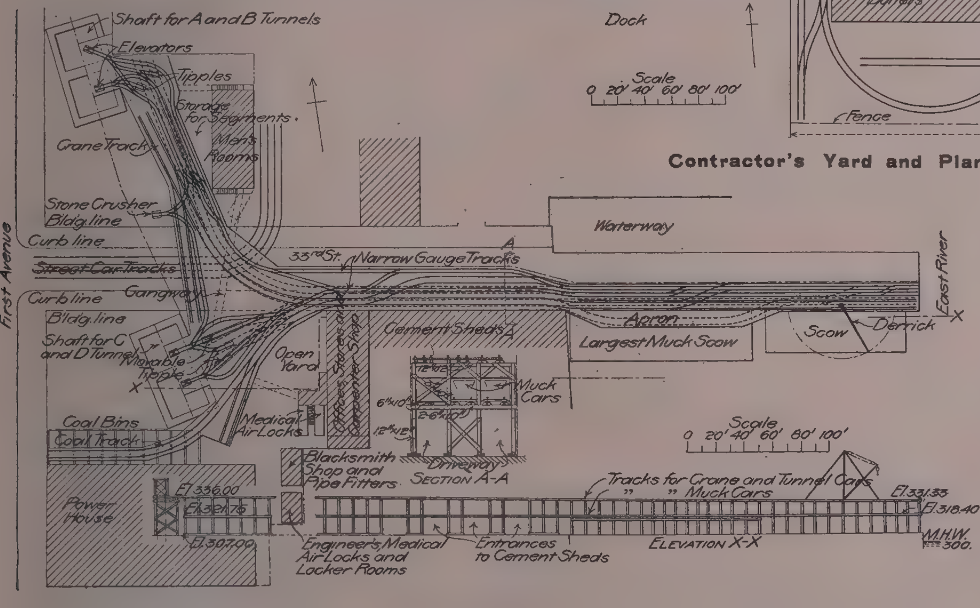
The dump cars have steel bodies about 6 ft wide and 8 ft. long on top and 4 ft. deep. The long sides are inclined inwards and are continuous with the rounded bottom. In the center of each end is riveted a segmental flange resting on a transverse beam supported by the steel truck. The car hangs between these two end transverse beams on the flanges, which are provided with spurs engaging holes in the upper flange of the beams, and serve as rockers on which the body is balanced so as to be easily reversible when full and to automatically swing back to position when empty. The tracks are graded 1 per cent. down toward the river so that trains of two or three loaded cars can be easily hauled by a single mule.

Part of the stone excavated in the tunnel is delivered from the shafts to the stone crusher where a plant is established for screening it and elevating it to storage bins which deliver it to the concrete mixer discharging into one-yard steel buckets which the traveling cranes load on cars running to the shafts on narrow-gauge tracks.

The cement storage house has a capacity of about 5,000 bags of cement, and its floor is level with the upper platform of the viaduct. It is of wood, like the buildings for the men's quarters, offices, stores and various shops. The 90x150-ft. power house has a steel framework with 90-ft. span roof trusses so that it is unobstructed by interior columns. It is well lighted by windows and skylights and has a substantial concrete floor and concrete piers for the foundations of the heavy masonry. In it are installed the principal units of the power plant and stationary machinery used at these shafts.

The equipment in this yard includes seven 500-h.-p. Stirling steam boilers, fitted with Cleve shaking grates, six 16 and 34-in. by 42-in. Corliss duplex compound low-pressure air compressors and one combination high and low-pressure compressor of the same size, two high-pressure, 90-lb. compressors all of the Ingersoll-Sergeant make, each of them having a capacity of 5,000 cu. ft. free air per minute; three 75-kw. General Electric dynamos, operated by three Reeves vertical engines; one Cochrane feed water heater; three Tannet-Walker high-duty pumps for the hydraulic service of 6,000 lb. pressure; three low-pressure feed-water pumps, one hot well and oil supply pump, one bilge pump, three 30-in. centrifugal pumps for cooling water, and three 6-ft. fans, all built by the Buffalo Forge Co.; three Wheeler condensers; three Edwards air pumps; two Masson-Scott oil separators; one Albion feed water regulator.

The plant installed outside of the power house includes two Fairbanks ash hoists, an Ingersoll-Sergeant Ajax drill sharpener, a Raymond pug mill, a Ransome concrete mixer, a Gates giant stone crusher, screens and elevators made by Allis-Chalmers and operated by two Lidgerwood hoists, two Cameron pumps in the shafts; two 5-ton steam traveling cranes made by J. H. Wilson, Liverpool, England; four 10-ton stiff-leg derricks furnished by the Terry & Trench Construction Co., and equipped with Lidgerwood hoisting engines and a number of Worthington pumps used for various purposes. There are a large number of ½-yd. grouting machines made by Cockburn & Barrow and operated by Ingersoll-Sargeant compressed air engines. The 4-yard dump cars and the metal work of the wooden tunnel cars was supplied by the Atlas Car Co., and the buckets, narrow-gauge cars and other apparatus is of various standard makes. The tipples, steel elevator frames, and in fact most of the special appliances used were designed and many of them built by the contractors.

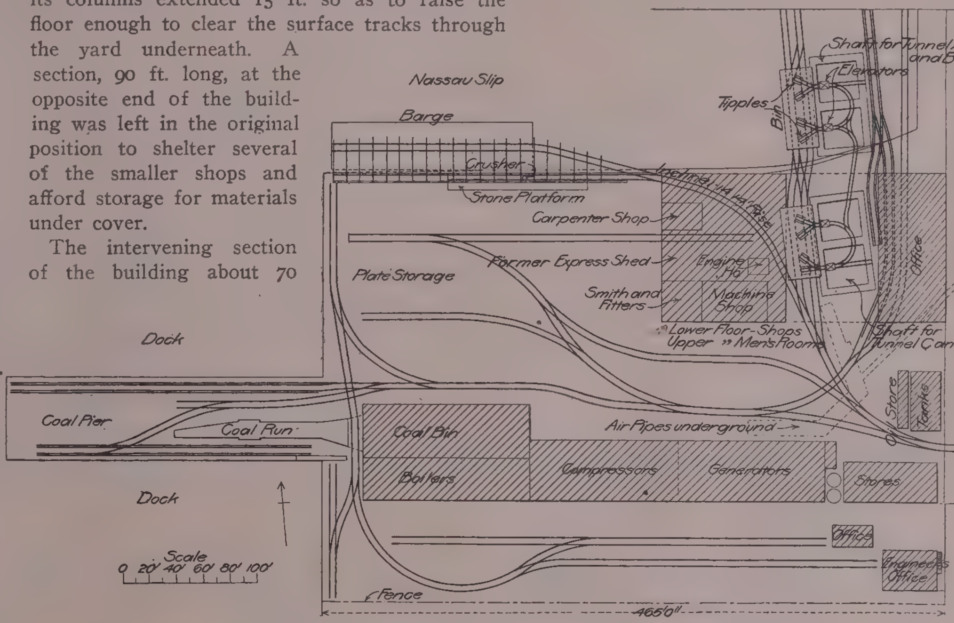


Plan of Yard and Elevation of Pier Tracks at First Ave. Shafts, New York.

The various shops in the yard are well equipped with heavy machinery for bolt and pipe cutting, forging and ordinary machine tools, together with those requisite for repair shops, carpenter shops, smith shop and saw mill and are operated in most instances by General Electric motors driving line shafts to which the different tools are belted. About 5,000 bags of cement chiefly of the Giant and Atlas brands and large quantities of iron tunnel segments and timber together with abundant supplies for the pipe systems and other requirements of the work are constantly kept in storage here, besides similar supplies independently maintained on the opposite side of the river.

In Long Island City the contractor's yard at the river shafts occupies an area of about 465 x 320 ft. exclusive of a portion of the Nassau Slip where one of the shafts is located and exclusive of a 60x240-ft. coal dock projecting into the river. This affords abundant space for tracks, storage, buildings and other requirements of the work, so that most operations are conducted upon the surface of the ground. There are no elevated platforms or trestles except where the tracks are carried out on the coal pier and to the dumps.

Part of the site was originally occupied by an express company's building which had steel columns and 110-ft. roof trusses covered with corrugated iron. A section of this building, 50 ft. long at the shore end, was reserved for the contractor's general offices and was jacked up and its columns extended 15 ft. so as to raise the floor enough to clear the surface tracks through the yard underneath. A section, 90 ft. long, at the opposite end of the building was left in the original position to shelter several of the smaller shops and afford storage for materials under cover. The intervening section of the building about 70 ft. long was disconnected from the two end sections. The roof trusses were lowered to the ground in sets of three and still remaining braced together in vertical planes were skidded about 70 ft. transversely, revolved 90 deg. and elevated to the tops of columns already erected, so as to form the roof of the power house, which like the one on the opposite side of the river is enclosed with corrugated iron and provided with concrete floor and machinery foundations. The movement of the roof trusses was thought advisable in order to locate the power house on solid ground. The original position of the building being directly over the tunnel it is feared that if the power house were established on it, there might be settlement injurious to the heavy machinery there. The four coal stacks for the boiler house are braced with riveted struts to avoid the use of guy lines extending over adjacent property. All of the tracks are run on the surface of the ground except where as indicated in the plan they are carried out over the water. The receivers from the air compressors are cross connected so that any one of them may serve any of the four tunnels and their pipes are connected from the power house to the shafts in an accessible trench just below the surface of the ground.



Contractor's Yard and Plant at Long Island City.

The spoil is hoisted from the shafts in small cars which are emptied by tipples into storage bins and 4-yd. rocker dump cars as described for the opposite side of the river. The 4-yd. cars are hauled singly or in groups by a wire cable and hoisting engine up a short incline with a rise of 14 ft. to an elevated platform cantilevered over the Nassau slip so that the cars can deliver from the edge of it to the barges moored below.

Cars of rock suitable for concrete are diverted from the dump track and discharge their contents on the opposite side of the platform adjacent to the stone crusher. From the crusher the stone is taken by an Allis-Chalmers bucket elevator to the top of a tower about 30 ft. in height where it is passed through cylindrical screens and the rejected portions are chuted back to the crusher. The screened stone is delivered continuously to side-flap dump-cars on the elevated platform which discharge it into the storage bin at the top of the concrete tower, to boats at the end of the pier, or, running in the opposite direction, deliver it to a 200-yd. storage bin with the bottom elevated about 5 ft. above the ground. A Ransome concrete mixing machine, installed in the lower part of the concrete tower, is fed by gravity from the sand and stone bins above, and discharges its contents into buckets on cars on a surface track which deliver them to the shafts.

The muck is not discharged directly from the 4-yd. cars to the scows, but is dumped instead on two inclined chutes parallel with the track. Each chute is about 6 ft. wide and 12 ft. long and is pivoted at the upper end to a horizontal axis transverse to the car track at the level of the base of rail. The lower end is suspended by a tackle from a cantilever beam transverse to the car track and it is thus adjustable to any height of tide and delivers the spoil as required to the scow.

A large quantity of coal, equivalent to an average of 100 tons per day, is received in barges which are unloaded by a derrick and a clamshell bucket delivering into an elevated hopper, which through a bottom gate fills small dump cars that are pushed out by hand short distances until they engage an endless chain which pulls them up an incline where they discharge their contents into chutes and are then automatically returned by gravity to the starting point.

Each shaft is fitted with two Ingersoll-Sergeant balanced elevator cages and as there is a difference of 3 or 4 ft. between the levels of the tunnel inverts in one of the shafts, the Lidgerwood hoisting engine which operates the cages in this shaft is made with two drums having their diameters varied enough to compensate for the difference in hoist. This arrangement proves very satisfactory and was suggested by a similar condition previously encountered by the contractors who on that occasion modified the existing drum by lagging it sufficiently to provide for the extra length of hoist. Eventually the elevators for the different tunnels will be provided with separate engines.

The caisson for the north shaft has been sunk to the final position, the temporary steel floor forming the roof of the working chamber has been removed, the tunnel shields assembled in the bottom of the shaft and the steel floor replaced above them. In its roof there have been built two vertical steel elevator shafts 10 ft. in diameter, one for each division of the caisson. The tops of these shafts are connected to transverse horizontal cylinders, 7 ft. in diameter, extending about 20 ft. beyond it in each direction and fitted with doors enabling them to act as air locks for the introduction of men and materials. Over the center of the vertical shaft there is an extension of smaller diameter above the top of the air lock and containing the hoist rope for the elevator cage which passes through a very long stuffing box in it and thence leads to the hoisting engine. After the tunnels have advanced far enough beyond the foot of the shaft the shore ends will be closed by the usual bulkheads and air locks. Permanent elevators with Ingersoll cages, steel frames and Lidgerwood hoisting engines will then be installed in the open air and during a convenient holiday, connection will be made with them to the foot of the shaft, the temporary floor and the T-shaped air locks will be finally removed and the change to the permanent operation of the outside elevators will be effected without interrupting the tunnel work.

The installation in the power house and the equipment of the yards in Long Island City are substantially the same as previously described for the First Ave. New York shafts, except that hydraulic power here is provided by three large pumps of English manufacture previously used by the contractors for the Blackwell tunnel work. There are also used here two standard gauge yard locomotives.

The engineer corps for the shaft and tunnel work is under the direction of Mr. Alfred Noble, chief engineer, and Mr. C. L. Harrison, principal assistant engineer, together with a staff of about 180 members including a comparatively small clerical force. Mr. Francis Mason, Mr. George Leighton, Mr. James H. Brace and Mr. S. H. Woodard are the resident engineers in charge of the work at the different shafts. Each thus has two tunnel headings and is provided with an assistant in charge of the alignment and another assistant in charge of construction. The alignment engineer has a field party with chief for each tunnel and the construction inspector who is stationed in the heading is always on duty in each tunnel where work is in progress.

He works under air pressure for two 2-hour shifts separated by a two-hour interval and spends the remainder of the working day in outside duties. It is his duty to inspect the permanent work, check the position of the shield and make the general records. With this organization, six inspectors are required in each heading to provide for continuous work throughout the 24 hours, thus making a force of 48 for the sub-aqueous tunnels alone when all their headings are advancing.

The contractors' organization consists of Mr. E. W. Moir, vice-president, of S. Pearson & Sons, Inc., who has his office in Long Island City, and exercises general supervision over the work; Mr. Henry Japp, resident managing director; Mr. A. W. Maulton, deputy managing engineer; Mr. C. F. Fraser, Manhattan general superintendent, in charge at Long Island City and Bush Ave; Mr. P. Riach and Messrs. Johnson and Davisberg, three assistant superintendents, three general inspectors, one for each eight-hour shift, four walking bosses for each tunnel, each of whom works two alternate three-hour shifts and thus completes the 24-hr. organization, and a corresponding number of tunnel foremen and gangs. Besides this, there are on the surface Mr. De Lacy, mechanical superintendent, a master mechanic, a power house engineer, a chief hydraulic foreman, and the foreman of carpenters, blacksmiths, electricians, machinists, pipe fitters, riggers, etc., all of them working day and night shifts. An important part of the organization is the medical staff under the direction of Dr. Keays, who has four resident physicians, one of whom is always on duty on each side of the river, and is assisted by two nurses constantly in attendance to care for cases of bends or other patients. The total force of men employed on this contract averages about 2,000 at the present time and will be considerably increased when work is in progress on all of the tunnel headings.

(To be continued.)

Operation of the Reading, England, Sewage Farm.

The Reading sewage farm consists of about 869 acres of land lying 1½ miles due south of Reading. The farm is intersected by the river Kennet for about 1½ miles, and by the Foundry Brook for 1¼ miles, the latter receiving the drainage of a district extending from Baughurst in Hants, and covering an area 8 miles long by 4 miles wide. Whenever there is an excess of rain the brook overflows its banks, flooding the adjoining fields, but in a dry season there is but little and sometimes no flow of water, except the sewage effluent.

Roughly speaking the irrigated land receives sewage three and a half years intermittently, and is then under potatoes and oats two and a half years, when the rotation is complete, and rye grass is again planted after the last crop of oats. In laying out 24 acres now under preparation for sewage, a somewhat different method has been adopted from that on the existing irrigated area planned by the late Mr. James Mansergh, where the single sewage carriers are 100 ft. and the double carriers 200 ft. apart, and the gradients of the carriers from 1 in 2,000 to 1 in 3,600. Mr. Thomas Chettle, manager of the farm, in describing the results of operation of the latter before the Association of Managers of Sewage Disposal Works, said he had found this distance too much apart for the sewage and the solids contained in it to become uniformly spread over the surface, and also the flow down the carriers so slow that the solids were deposited within a comparatively short distance from the outlet of the distributing box. He, therefore, reduced the spacing of the single carriers to 75 ft. and the double to 150 ft., and increased the gradient to from about 1 in 600 to 1 in 750.

This, of course, is somewhat more costly in leveling, but Mr. Chettle is satisfied that it will be a great improvement in keeping the sewage moving till absorbed, and also in more even distribution of the solids, a point which troubles exceedingly few sewage farms, as nearly all have the solids precipitated in tanks previous to land treatment; but there, Mr. Chettle said, exists also the enormous expense of dealing with the sludge, as well as the nuisance arising from it.

Mr. Chettle has also found it necessary to carry out the land draining in a different method to that usually adopted; for, owing to the naturally low-lying land, it is practically impossible to treat the sewage more than once, as is done at Leicester, Tonbridge, and other places in England, where the first effluent can be again used on the lower-lying land. Therefore, each bed is treated as a separate filtering area, the main drain running up the center of each double bed with the laterals 30 ft. apart in herring-bone pattern, but the laterals are not carried within 10 ft. of a sewage carrier. The mains are 12, 9, 6 and 4, and the laterals are 3 in. The main laterals are laid to the same gradient as the surface, so as to get a uniform depth of soil for filtering. The drains, wherever the outfall ditches will allow it, are laid 4 ft. to 4 ft. 6 in. deep, as owing to the very uneven character of this soil and subsoil, it is necessary to go as deep as possible, since the filtration efficiency of a bed is governed by its most porous soil.

Boiler Priming Caused by Poor Circulation.

Some experiments have recently been made by Prof. D. S. Jacobus, of Stevens Institute, Hoboken, N. J., to demonstrate how priming in a boiler may be caused by the poor circulation of the water contained therein. A small vertical tubular boiler of ordinary construction was used, with the water-heating surface enclosing a circular grate and with tubes leading directly upward from the combustion space above the fire to the upper tube-sheet at the top of the boiler. The steam was taken from the boiler at a point in the outer shell near the top of the boiler. When the boiler was operated under normal conditions the steam generated was dry for ordinary rates of combustion, and superheated when the fires were forced.

In this class of boiler the temperature of the flue gases escaping from the tubes near the center of the tube-sheet is much higher than that of the gases from the outer tubes, and tests were arranged to determine whether there would be a gain in the economy through placing retarders in the center of the tubes so as to distribute more evenly the work done by the different tubes. In these tests the retarders were so adjusted that the temperatures of the escaping gases were made about the same for each of the tubes. After this was done there was an unexpected action through the boiler priming so severely that it was impossible to operate it at other than a low capacity. The water level would be constant for a short time and the steam would be dry, when suddenly water would be thrown from the boiler along with the steam. On removing the retarders the priming disappeared, and on replacing them it was again present. From this it would appear that the retarders were the cause of the boiler priming.

Without the retarders the tubes near the center of the boiler were hotter than those near the side and caused an upward current of water at the center of the boiler and a downward current of water at the sides, the circulation of water being brisk and definite. With the retarders, however, all the tubes were at the same temperature and there was no tendency to produce a definite circulation, so that the water was for a time quiescent until after storing a certain amount of heat it would foam up and some of it would be thrown from the boiler.

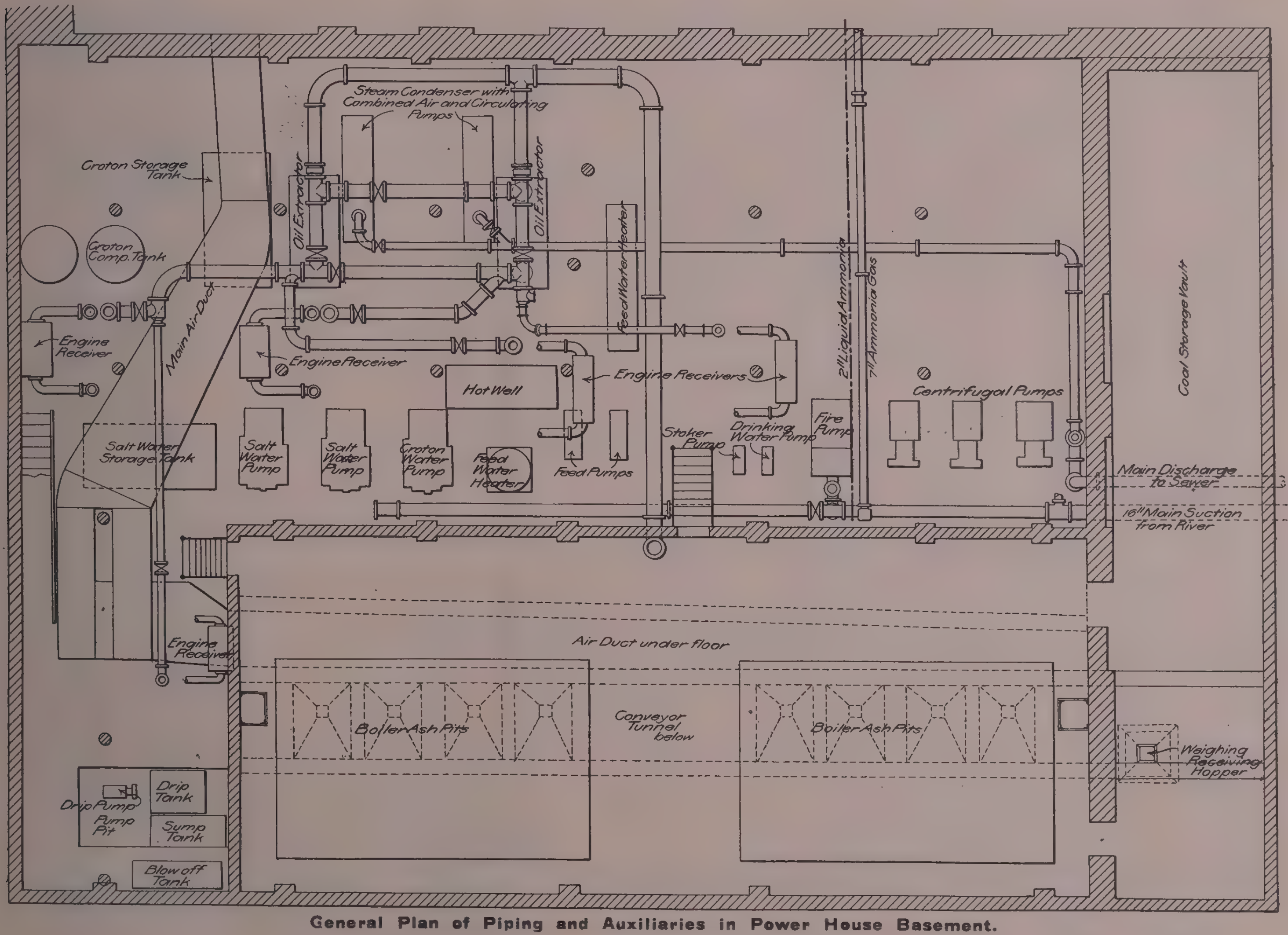
Power Plant of the New Abattoir in New York City.

The power installation of the new abattoir plant of the New York Butchers' Dressed Meat Co., the general mechanical equipment and refrigeration system of which have been referred to in articles in preceding issues of this journal, is one of the most interesting features of that plant equipment. This installation comprises a 1,600-h.-p. boiler plant, with extensive coal storage facilities, an electric generating equipment of an aggregate capacity of 1,000 kw. and refrigerating machinery with a total capacity of 250 tons of refrigeration per 24 hr. The large boiler capacity was necessitated by the extensive use of steam for cooking purposes in addition to the operation of the electrical generating units and refrigerating machines, while electric power and lighting is required in quantities in all parts of the plant. The power equipment is housed in a 78x98-ft. power house located at the rear abattoir property at Thirty-ninth St., adjoining the fat-rendering house to the rear. The building is of steel and brick construction, with limestone trimmings, and is divided into two sections, one for the boilers 34 ft. in width by 77 ft. long, while the remaining 44 ft. in width and the L-shaped projection at the rear is devoted to an engine-room. The engine-room has a 12-ft. basement for the pumps, condensing equipments and other auxiliaries, while the boiler-room is depressed to a level 8 ft. below that of the engine-room floor and from there extends to the roof, containing the coal storage bunkers above the boiler. Above the engine-room two floors have been finished off, on a level with and connected into the third and fourth floors of the fat house adjoining, and are devoted to the oleo filter presses and other machinery of the fat-rendering plant. The upper portion of the building is a length shorter than that of the engine-room only, so that over the rear of the engine-room, skylighting was permissible, which affords unusual daylight lighting in the engine-room. All portions of the building devoted to power equipment are of fireproof construction, concrete floors being used throughout, including the floor above the engine-room; the construction of the two floors above the engine-room are, however, of mill construction, to correspond with that of the fat house, which was considered more suitable for the processes involved.

An interesting feature of the power house construction was the displacement of brick in a number of places by concrete. When the building was nearly completed, labor difficulties were encountered with the bricklayers and in order to hasten completion, recourse was had to concrete for the upper portions of the building walls and also for the boiler settings. The ornamental cornice construction on the upper front of the building was changed to galvanized iron and was quickly and effectively backed up in concrete which serves the purpose equally as well as brick. The boiler settings had only been begun in brick and they were similarly completed in concrete without further delay or difficulty. It is interesting to note that in operation no trouble has resulted from this form of construction due to heat from the boiler furnaces, no cracks having developed and in addition very little heat is radiated from the settings, resulting in a very cool boiler-room.

The steam generating equipment of the plant consists of four Stirling water-tube boilers of 400 h.-p. capacity, each, which are set in two batteries of two each, one battery on either side of the centrally located stack. The use of this type of boiler makes available in the 34-ft. boiler-room, a 10-ft. firing floor space in front of the settings, and a 3-ft. space at the rear, for access to the blow-off piping and connections. The stack is supported on a heavy structural steel platform incorporated in the building construction at a level of 23½ ft. above the boiler-room floor, so that the space beneath, 14 ft. in width, is available for auxiliary machinery, and for the renewal and repairing of boiler tubes. At either end of the boiler-room is a 40-in. space which serves as a passage and also accommodates the vertical legs of the coal conveyor system.

The boilers involve the standard Stirling construction with inclined tubes, each boiler occupying a ground plan of 14 x 18 ft. with a height of 20½ ft. over all. Each has three steam drums 42 in. in diameter by 14 ft. long and a 42-in. mud drum 12 ft. long, the boiler heating surface of 4,000 sq. ft. being made up of 321 tubes, 3¼ in. in diameter. The boiler drums are built of 11/16-in. steel plate and all construction is extra heavy, the boilers being designed for operation at 150 lb. pressure. The boilers are stoked mechanically, each being equipped with two Wilkinson inclined reciprocating grate stokers, furnished by the Wilkinson Mfg. Co., Bridgeport, Pa. The inclined grates are 7 ft. wide and 5 ft. in length with a 24-in. clinker plate at the bottom, beyond which is a 24-in. dumping gate next to the bridge wall for dropping ashes into the ash pit. An arch covers the stoker grate, the springing line of which is 3½ ft. above the clinker plate, and which extends back to within



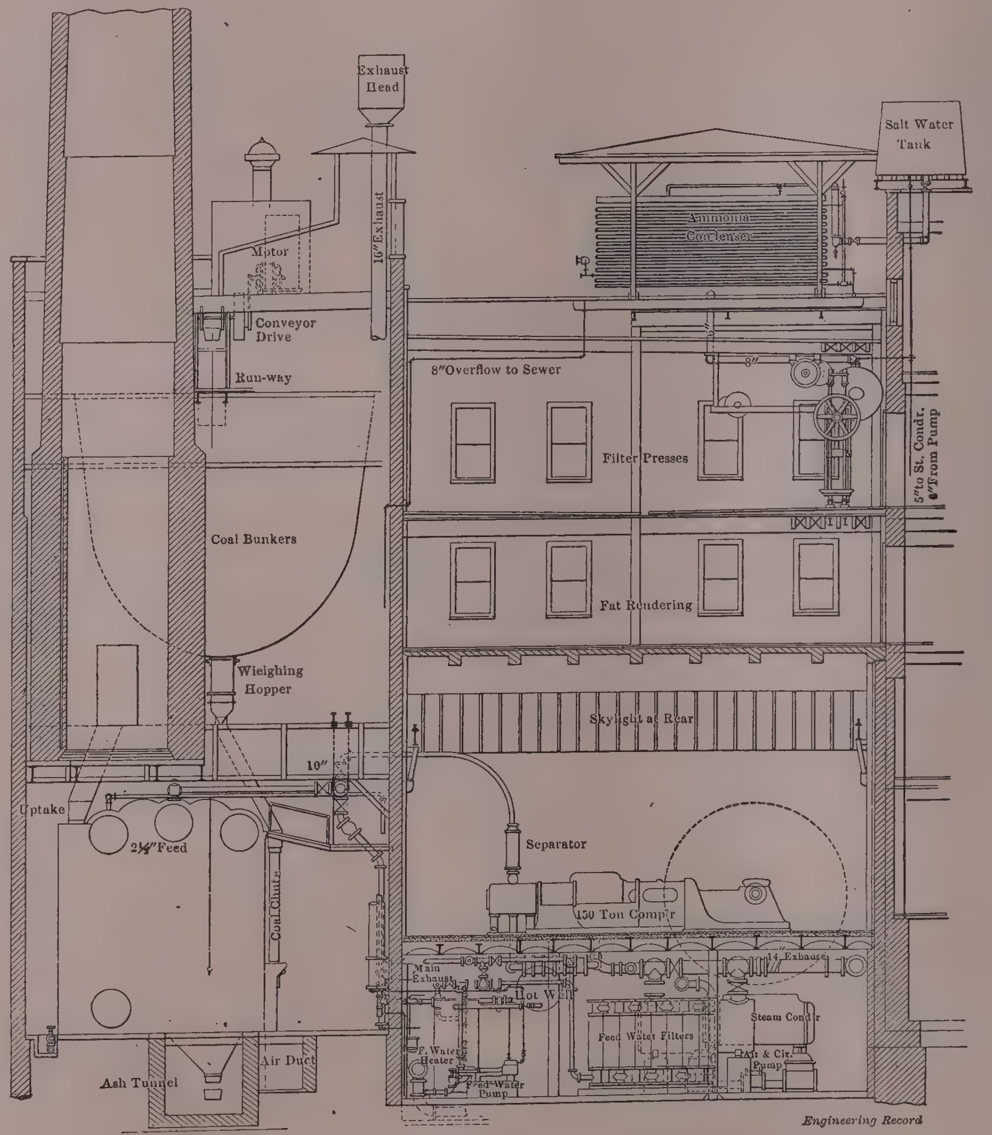
General Plan of Piping and Auxiliaries in Power House Basement.

2 ft. of the first row of boiler tubes; this arch, instead of being built of fire brick was also constructed of cinder concrete. The stokers are operated by hydraulic motors mounted on the boiler fronts which reciprocate the inclined grates at varying speeds, in accordance with the requirements of the boilers. Hydraulic pressure supply is furnished by a pump and receiver in the engine-room basement, on which the steam pressure acts to vary the speed of the pump and hydraulic motor, shutting off the latter as the steam pressure rises in excess of requirements. Forced draft is used in connection with the stokers, which is furnished by steam jets arranged below the inclined grates. The air supply for the furnaces is taken in through a tunnel, 4 x 5 ft. in section, beneath the firing floor, which is connected with the ventilating system of the fat-rendering plant, the foul air from which is thus passed through the furnace fires for deodorization, before exhausting to the atmosphere; the details of the ventilating system were referred to in an article on the abattoir in The Engineering Record for June 30.

The products of combustion are removed by a 150-ft. brick chimney, which was built of hollow radial blocks by the Alphons Custodis Chimney Construction Co. It is 8 ft. in diameter and has 3½x7-ft. openings at the base upon either side for the uptake connections from the batteries of boilers. It is lined to a point 24 ft. above the uptake openings with fire brick, but is unlined above that point. An interesting feature of the construction of the chimney is that it is supported upon a structural steel platform at a point 23½ ft. above the boiler-room floor. The platform construction was fully described in an article descriptive of the abattoir building construction in The Engineering Record for July 7.

Both fuel and ashes are handled at the plant mechanically throughout, coal being received through a sidewalk hole in front of the building and elevated thence by an endless bucket conveyor to storage bunkers above the boiler-room for delivery by chutes directly to the stoker hoppers. The conveyor system has been so located that, on its lower run, it passes beneath the ash pit hoppers under the boiler furnaces and is thus available for elevating the ashes also to a storage bin from which it is removed by chutes to ash carts for removal. The conveyor system has a horizontal run of 72 ft., with an extension of 16 ft. beneath the sidewalk to receive coal from the sidewalk hopper, and has a vertical rise of 67 ft. from the ash pit run to the run above the bunkers. It is operated by a 7½-h.-p., slow-speed motor, which is located above the bunkers and drives to the upper run through reduction gearing. The motor operates at 600 r.p.m. and drives the conveyor at lineal speed of 50 ft. per minute, at which speed it has a capacity of 50 tons per hour. The conveyor system was installed by the Exeter Machine Works. At the receiving hopper beneath the sidewalk is a bucket loader to fill the buckets evenly and without spilling, and above the bunkers there are automatic trips for dumping the buckets at any point desired. Coal is weighed upon receipt by the receiving weighing hopper which is suspended underneath the sidewalk coal hole with scale beams for measurement. This hopper is of ⅜-in. steel and has a capacity for weighing 3 tons of coal at a time. Coal is also weighed out of the bunkers, as used, by automatic weighing scales of the Richardson patent, incorporated in the delivery chute connections beneath the bunkers. The latter are 14-in. chutes which end in swinging outlet connections over the stoker hoppers for distributing coal to any part of the stokers. There is in addition to the bunker storage, an auxiliary coal storage vault beneath the sidewalk which is available in case the coal conveying machinery is out of commission; this vault is on a level with the firing floor permitting coal to be wheeled in and stoked by hand.

The coal is stored in two 450-ton steel coal bunkers, of the Berquist suspension type, one of which is located over each battery of boilers. The details of this construction were also referred to in the article in the issue of July 7. A section of the bunker nearer the street is partitioned off for the storage of ashes, from which a discharge chute leads down outside the building for delivery to ash carts on the sidewalk. The lower run of the conveyor is carried through a tunnel 7 ft. wide and 6 ft. high beneath the boilers, into which the ash pit hoppers project with gate valves opening directly over the line of the conveyor, into which they are dumped without handling. For convenience in the handling of ashes, rope control lines are carried down from the upper run trip of the conveyor above the ash bunker so that it may be thrown into operation from the ash tunnel when ash pits are dumped.



Transverse Section of Power House.

The boilers are fed by an equipment of two 7½x5x6-in. Worthington feed pumps, which are supplemented for testing and emergency purposes by two 2½-in. Monitor injectors. The pumps, which are located in the engine-room basement, are outside packed plunger duplex steam pumps and are brass fitted for the handling of hot feed water. The injectors are mounted in the boiler-room, on the division wall with the feed piping connections, all of which are convenient of access from the firing floor. The feed pumps take suction from the feed water heaters through a 4-in. line and deliver to the boilers through a system of feed piping, involving a 4-in. longitudinal header in the basement with a 3-in. branch to each battery of boilers. The 3-in. branches are in either case brought up from the basement through Worthington hot-water meters also on the division wall in the boiler-room, from which 2½-in. branches are extended to each boiler-feed connection. The injector delivery connection is made t othe feed lines at this point. The injectors have a 2½-in. water supply connections from the city water service and also there are 2½-in. by-pass connections from the city service to the feed piping for the filling of boilers when cold. All of the feed piping, both the pump suction and delivery, is of extra heavy brass pipe with beaded fittings.

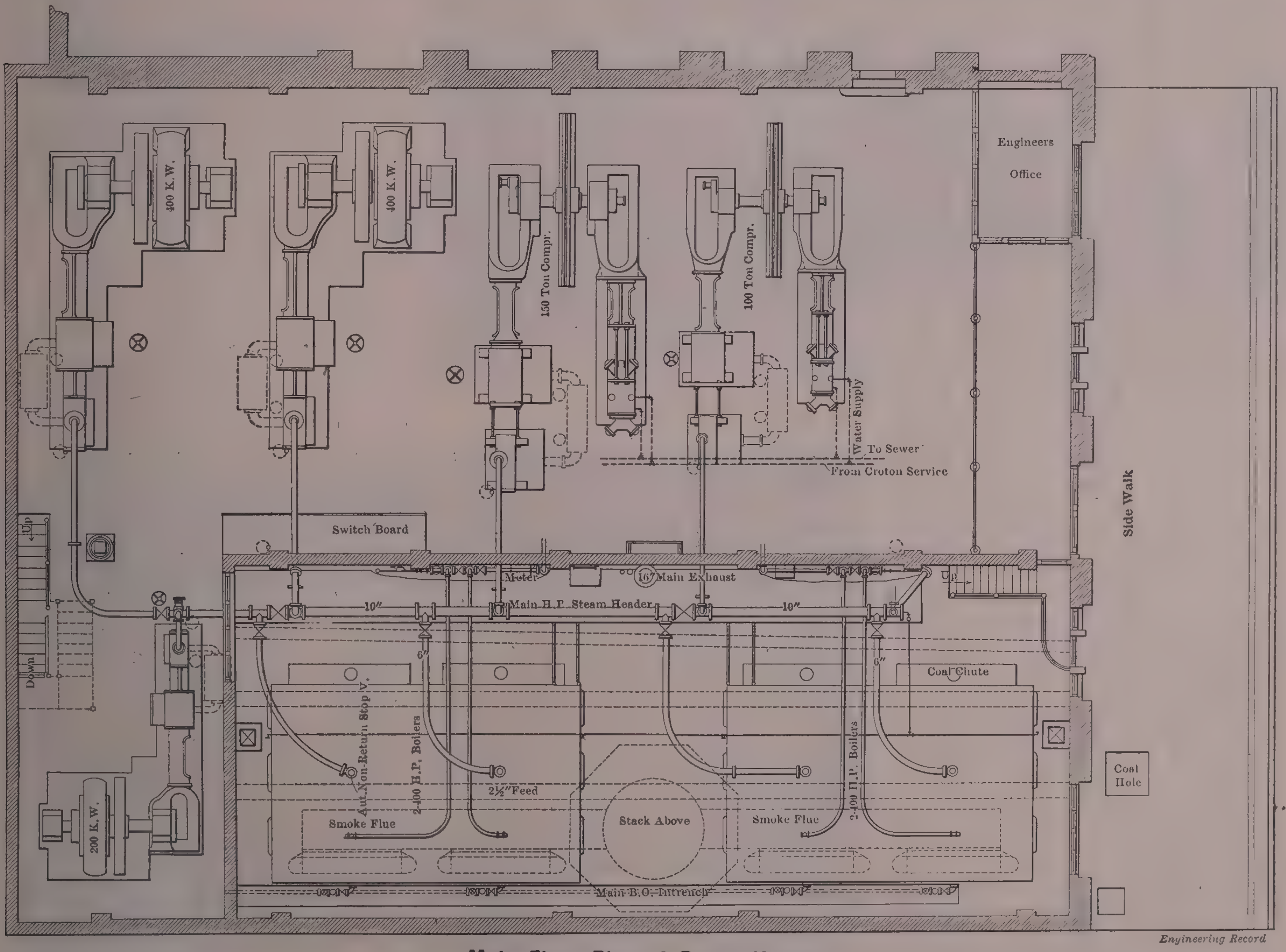
The feed water is heated in a 1,000-h.-p. Cochrane open heater located in the engine-room basement near the feed pumps and directly connected to the auxiliary exhaust steam main by a 4-in. branch. The heater is fitted with an attached oil separator for removal of oil from the exhaust, and also has a filter for purification of the feed delivery. For further purification of the feed before entering the boilers, there is also a Ward feed-water filter connected between the pump delivery and the feed header in the basement. This filter has ten filtering cylinders 15 in. in diameter by 50 in. high which are connected with return bends and have surface and bottom blow-offs.

for cleaning. The cylinders are packed with animal charcoal for the filtering process and have zinc slabs at the inlets. The boiler blow-off system consists of 2½-in. blow-off connections from the mud drum of each boiler which connect through Y-fittings into a blow-off main of 3-in. pipe. Each boiler branch has two blow-off valves in tandem, one a special plug cock and the other a blow-off gate valve, with a pet cock in the fitting between for drainage. The blow-off main is located in a trench in the floor 18 in. wide by 18 in. deep, in the space at the rear of the boilers. All of the blow-off pipe is of extra heavy brass, specially fitted for cleaning, and delivers into a 3x7-ft. steel-plate blow-off tank in the rear of the basement. This tank has a 4-in. vapor connection carried up to an exhaust head above the roof and a 2½-in. connection to the sewer, which connection is so made that the tank remains always partly filled, for cooling the blow-off discharged into it. For further cooling, there is installed in the tank a brass return-bend coil with eight lengths of pipe, through which the city water supply to the hot-water tanks is passed for thus conserving a portion of this waste heat.

In the installation of machinery in the engine-room, the unusual practice of locating the reciprocating engine units on the beams of the floor construction was resorted to, in order to secure free working space in the basement underneath. By thus doing away with the massive foundations that are ordinarily used for units of these sizes, an excellent working space was obtained which permitted a most advantageous arrangement of the auxiliary equipment, particularly the central condensing apparatus to which short direct connections were made from the engines. Special floor construction was designed to carry the loads and provide sufficient stability to withstand the vibration of the engines, the details of which were also referred to in the article in The Engineering Record for July 7. A remarkable freedom from vibration has been experienced with this construction, the stability of the structure proving to be such that the delicate electrical instruments on the switchboard, which faces and is close to the 400-kw. generating unit, are not in the least affected. While this is a practice that is believed not to have been extensively used, it is apparently susceptible of successful treatment where conditions make it desirable.

The engine-room contains an equipment of refrigerating machinery for the operation of the abattoir cold storage and electrical generating units for the power and lighting service. The refrigerating units embrace a 100-ton and a 150-ton Vilter ammonia compressor, both of which have horizontal single-cylinder, double-acting compressors, operated by tandem-compound Corliss engines. The engine of the 150-ton machine has 16 and 30 by 42-in. cylinders, and a 16-ft., 12-ton flywheel; that of the smaller engine, 15 and 28 by 36-in. cylinders and a 14-ft., 8½-ton flywheel, the flywheel shafts of the two engines being 12 and 11 in. in diameter, respectively. The compound cylinders have steam-jacketed receivers connected between them, the receivers being located in the basement. Both units are operated condensing, their exhausts connecting with a central condensing equipment in the basement, which also serves the generator engines. There is additional space in the engine-room available for another 100-ton unit, if required for future extension.

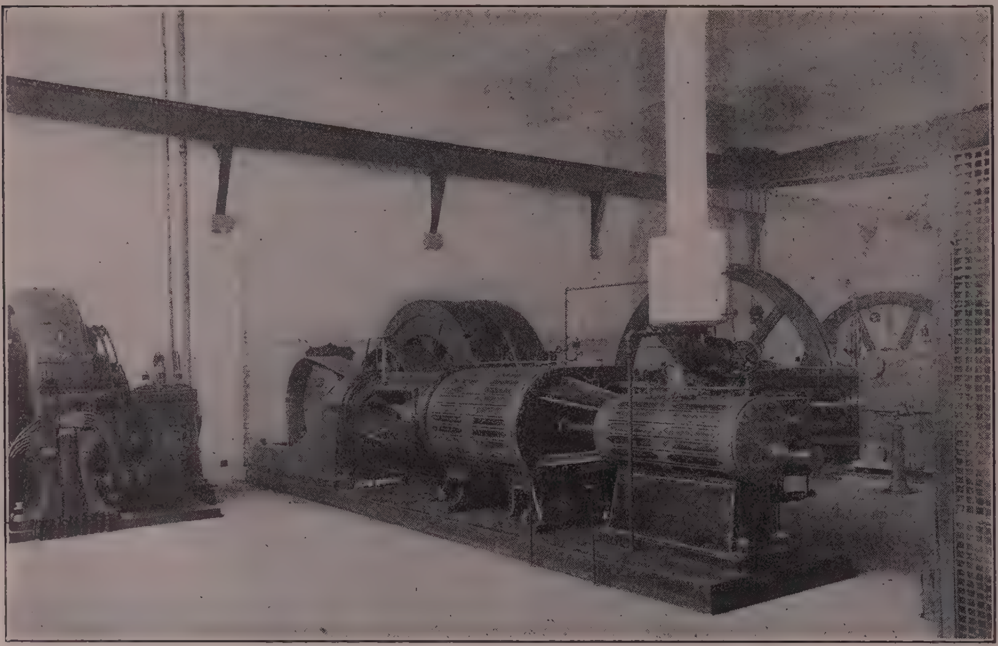
The electrical generating equipment consists of two 600-h.-p. and one 300-h.-p. Fitchburg tandem-compound horizontal engines, direct connected to two 400-kw. and one 200-kw. General Electric slow-speed engine type generators, which are located to the rear of the engine-room behind the compressors. The engines are of the four-valve automatic cut-off type with heavy duty tangye frames, and have double eccentrics for independent operation of admission and exhaust valves, the admission valves of both cylinders being under the control of the governor. The governors are of the centrifugal shaft type designed to provide for a long range of cut off and regulate within 1½ per cent. The valve gearing operates to give the results of the Corliss gear, a special cam motion being used which gives prompt admission and rapid cut-off, and by means of it, the cut-off is the only factor that is varied, the lead, release point and compression remaining always constant. The valves are of a balanced expansible double-ported piston type designed to give small clearances. The 600-h.-p. engines have 17 and 34x36-in. cylinders and operate at 120 r.p.m., developing rating at 23 per cent. cut off. The 300-h.-p. engine has 12 and 24x26-in. cylinders and operates at 150 r.p.m. The engines are all designed to operate with 150-lb. pressure and a 26-in. vacuum, the larger units having 6-in. steam supply connections and 12-in. exhaust outlets while the 300-h.-p. unit has a 4-in. throttle connection and 8-in. exhaust. These engines were built by the Fitchburg Steam En-



Main Floor Plan of Power House.

gine Co., Fitchburg, Mass., and installed by E. H. Ludeman & Co., New York.

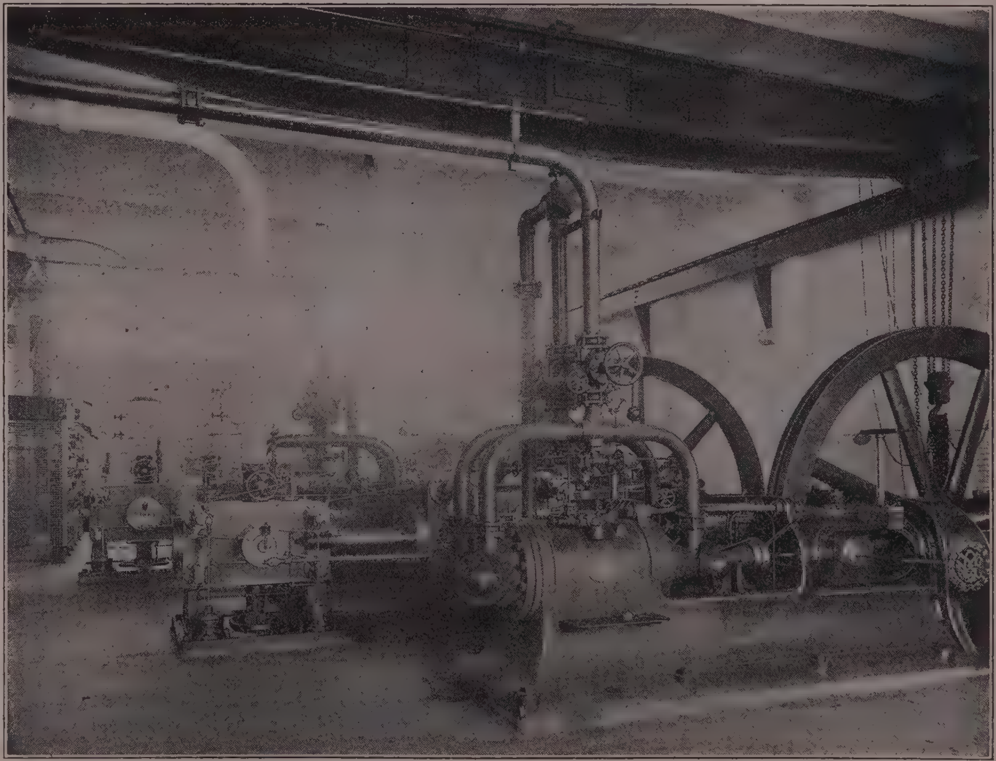
The generator equipment consists of two 400-kw. and one 200-kw. General Electric compound-wound dynamos, which are direct connected to the 600 and 300-h.-p. engines, respectively. They are wound to deliver 250 volts direct current, on the two-wire system, and are over-compounded 5 per cent. for maintenance of voltage under fluctuations of load. They are of the six-pole type with drum-wound ring armatures, and have out-board bearings. The machines are designed for 93½ per cent. efficiencies in the larger sizes and 91¾ per cent. in the smaller unit and all are capable of sustaining 25 per cent. overloads continuously. The load on the electrical system embraces 1,500 incandescent lamps and 75 arc lamps connected and a motor load of about 500 h.-p. The electrical installation was made by Johnston Livingston, Jr., & Co., New York.



Electric Generators in Engine Room.

The high pressure steam piping system consists of a 10-in. main header in the boiler-room with 6-in. connections to the boiler nozzles, each of which is valved at the header connection, and has a 6-in. Pearson angle stop-check-valve at the boiler nozzle. The latter connections are made with long-radius horizontal bends, owing to restricted head room, the header being on a level with the tops of the boilers. The header is conveniently located at a point 21 ft. above the floor level, below which is a pipe gallery 5 ft. in width, for access to the valves. The header is divided into three sections for localization in case of breaks, repairs, etc. The outside sections are supplied by the end boilers of the plant, and the middle section by the two inner boilers. The outer section feeds the 100-ton, ammonia compressor and a 6-in. connection to an auxiliary main in the basement; the middle section feeds similarly the 150-ton ammonia compressor and a second 6-in. line of the basement, and in addition, one of the 600-h.-p. generator engines; the rear section supplies the second 600-h.-p. and the 300-h.-p. generating engines. The two ammonia compressors for the refrigeration system are supplied by 4-in. branches from the steam header while the 600-h.-p. engines are supplied by 6-in. branches and the 300-h.-p. engine by a 4-in. branch. These are all made through long radius vertical bends extending through the division wall and have Cochrane direct steam separators at the engine throttle connections.

The auxiliary steam main in the basement is a 6-in. header supplied by the two 6-in. down connections from the main steam header at either end and serves the various pumping units in the engine-room basement. There is also a 6-in. connection extended from it through the basement to the fat-rendering house and to the abattoir building proper which supplies heating connections for both buildings and also the cooking connections for the fat-rendering tanks and the Power system apparatus. The steam connections for the auxiliary header involve 3-in. branches to the feed pumps, a 3-in. branch to the underwriters' pump, a 3-in. branch to the condenser pump, and of smaller sizes to the stoker pump, to the drinking water pump, to the air compressor, to the drip pump and to the hot-water heater. The branch supplying the fat-rendering house is a 6-in. main with risers to the steam using apparatus on the upper floors, while that to the abattoir building is a 4-in. line. Both these connections have pressure reducing valves for supplying the apparatus at a pressure of about 30 lb.



Refrigerating Units in Engine Room.

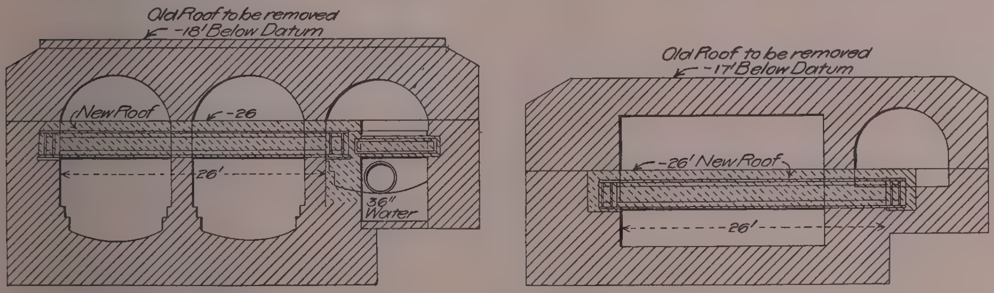
The exhaust piping is installed entirely in the engine room basement and consists of a 14-in. low-pressurt header into which the ammonia compressor engines deliver through 8-in. connections, the two 600-h.-p. engines through 12-in. lines and the 300-h.-p. through a 8-in. connection. This header has connections to both units of the duplicate condensing equipment, which are made through oil extractors. These connections are by-passed and cross-connected in such a manner that sufficient flexibility is obtained to meet all possible conditions of operation. This arrangement is especially arranged for convenience in testing of engines if desired, permitting any engine to exhaust into a separate condenser for measurement of its steam consumption. The exhaust system has at the rear two 14-in. atmospheric relief connections which are made through Foster back-pressure valves to a common 16-in. line leading to a roof exhaust head over the boiler-room.

The condensing equipment consists of two Admiralty surface condensers, built by the Wheeler Condenser & Engineering Co., in duplicate, each of which has a capacity of condensing 16,000 lb. of steam per hour. They each have a condensing surface of 1,600 sq. ft., the design being for the use of a maximum of 30 lb. of circulating water per pound of steam condensed. The circulation pumps which have a capacity delivering 500,000 lb. of water per hour, are brass fitted for handling salt water, the circulation supply being taken from the Hudson River through a 16-in. suction main extended under Thirty-ninth St. to the river front and out 500 ft. under the pier into the river. The air pumps deliver the condensation from the condensers into a hot-well tank suspended from the ceiling of the sub-basement; this is a cylindrical steel tank 4 feet in diameter by 10 ft. long and from it condensation is delivered to the open heater for boiler feeding. Compressed air supply for the plant is furnished by an equipment of two 11-in. Westinghouse locomotive-type steam air compressors in duplicate which are also installed in duplicate. These are designed for delivery at pressures from 50 to 80 lb. by means of an automatic governor. The pumps deliver to a storage tank, 24 in. in diameter by 42 in. long and from this a 2-in. main leads to different portions of the fat-rendering and abattoir buildings for various uses. Air lines are also run into both boiler and engine-room for cleaning purposes. The engine room is traversed by a 15-ton traveling crane for convenience in lifting machinery parts. It is a hand-operated crane with a span between runway rails of 38 ft. 10 in. and has a vertical hook movement of 20 ft. The hoist is a two-speed spur-geared sprocket hoist. The crane is of the curved girder type having a 22-in. girder. The crane was furnished by the Northern Engineering Works, Detroit, Mich.

The power plant was designed by Horgan & Slattery, New York, who acted as architects for the building construction and also engineers for the mechanical equipment in consultation with Pattison Bros., consulting engineers, New York. Of the former company, Mr. Arthur J. Horgan, Mr. E. T. Macdonald, chief assistant architect, and Mr. Arturo Rodriguez, chief engineer, gave special attention to the design to fulfil the requirements of the abattoir service.

Lowering the Tunnels Under the Chicago River.

The lowering of the three street railway tunnels under the Chicago River will apparently be undertaken immediately, as the city council of Chicago has approved the plans and specifications that have been prepared for the work on two of them by Mr. Samuel G. Artingstall, and plans have been completed for lowering the third. One of these tunnels is under the main branch of the river at La Salle St., about 1¼ miles from the mouth of the river in Lake Michigan; the other two, one at Washington St. and one near Van Buren St., are under the south branch of the river at about 1¾ and 2¼ miles, respectively, from the mouth of the main branch of the river The Van Buren St. tunnel is owned by the Chicago Union Traction Co., the corporation operating the surface street railway lines on the north and west sides of the city. The other two tunnels are both owned by the city, but are used exclusively for street railway traffic by the Chicago Union Traction Co. The La Salle St. and Washington St. tunnels are to be lowered at once under the direction of the city. The one at Van Buren St. will be lowered at the same time, but its reconstruction does not come under the supervision of the city. All three tunnels are brick structures. The La Salle St. tunnel has three longitudinal divisions separated from each other by the bench walls of the brick arch of each division. One of these divisions was built for a footway, but is little used as such at the present. The other two divisions each carry a street railway track. The Washington St. tunnel was originally arranged in the same manner, but has recently been rebuilt so that the car tracks are now both in the one division.



Cross-Section of La Salle and Washington Street Tunnels.

The top of the Washington St. tunnel is only 17 ft., and the roofs of the other two tunnels 18 ft., below Chicago datum, which is extreme low-water level in Lake Michigan. The fluctuations in the stage of the river due to changes in the level of Lake Michigan and to other causes reduce these clearances to 14 and 16 ft., respectively, under certain conditions. The obstruction offered to navigation by these tunnels since the introduction on the Great Lakes of large boats of deep draft has been so great that the lake traffic entering the Chicago River has been limited to smaller craft, with the result that the commerce of the city has undoubtedly suffered to a great extent.

The city was ordered by an act of Congress passed in April, 1904, to alter the La Salle St. and Washington St. tunnels by April 15, 1906, so that a depth of at least 22 ft. should be provided in the river channel over both tunnels. The Union Traction Co. was also ordered by Congress to lower its tunnel at Van Buren St., so that a clearance of at least 21 ft. would be provided in the channel above it. The three tunnels all carry important street railway lines, which are at present operated by cable. The condition of the franchises granted to the street railway companies by the city was such that no steps were taken to lower the tunnels by either the city or the Union Traction Co., until a recent decision handed down by the United States Supreme Court defined the present status of these franchises. Since the decision was rendered, plans have been formulated under the direction of the Commissioner of Public Works of the city for the substitution of overhead electric trolley for the cable on the street railway lines using the tunnels, and the transfer of these lines from tunnels to bridges crossing the river near the respective tunnels, pending the lowering of the latter.

The plans developed by Mr. Artingstall for lowering the tunnels contemplate the building of a new roof within the bore of the tunnel, the top of which roof will be flat and will be 26 ft. below the mean water level in the river. This new roof will be carried chiefly by unusually heavy built-up 36-in. steel I-beams, placed transversely across the tunnel, with their ends resting on the brick side walls of the tunnel. These beams will be imbedded in concrete and will be covered with a heavy layer of concrete covering a thickness of waterproofing. This new roof will be completed and the tunnel made watertight where the roof connects with the old brickwork, after which the arches and walls of the old tunnel will be removed down at least to the level of the top of the new roof, which will then become the permanent roof of the tunnel. The floor of the tunnels will afterward be lowered until sufficient clearance is provided to permit street railway cars to be operated in them, and the approaches will be lowered to connect with the new grades. Then the street railway lines that have been diverted temporarily to the bridges crossing the river will be operated through the tunnels again.

The lowering of the river sections of the three tunnels will be started immediately, after which the approaches will be lowered to the proper grades. The river has a total length of 291 ft. over the La Salle St. tunnel. The roof of this tunnel will be lowered to 26 ft. below Chicago datum for a width of 191 ft. at the center of the channel. This depth will be decreased gradually to 22 and 23 ft., respectively, at the two dock lines, 50 ft. from the ends of the 26-ft. depth. The South branch of the river is to be 200 ft. wide between the newly established dock lines over the Washington St. tunnel. For a width of 100 ft. at the center of the stream the tunnel roof will be lowered to provide a clearance of 26 ft. The clearance at the dock lines will be 23 ft. in each case, the reduction being gradual on each side of the 26-ft. channel. The Van Buren St. tunnel will have its river section lowered in about the same way the Washington St. tunnel is to be lowered, the river being 187 ft. wide at the crossing.

The reconstruction of these tunnels will doubtless be carried on with considerable difficulty. The steel girders carrying the new roof will be spaced 4 ft. apart on centers. They will have to be built up in place, as they weigh 4 tons each and could not be handled in the limited working space afforded in the tunnel. The footway in the La Salle St. tunnel carries a 36-in. city water main, which will have to be lowered when the tunnel floor is lowered. Washington St. is carried over the South branch of the river on a center pier drawbridge. This pier rests on the Washington St. tunnel roof, and is to be removed before the work of lowering that tunnel is started. A number of conduits carrying electric feeder wires are also laid in all three tunnels and these wires will have to be continued in service during reconstruction of the tunnels.

The work is all to be done by contract at the expense of the Union Traction Co., and under the supervision of the Commissioner of Public Works of Chicago. The contractor is required to keep the river channel free and unobstructed during the season of navigation so as not to interfere with the movement of vessels. The existing roofs of the tunnel are to be destroyed as much as possible from the under side after the new work has been made tight, then the space between the new roof and the old work will be packed with clay, or other suitable material to act as a cushion. After this cushion of earth is placed, the old roof will be removed in such a manner as to avoid as much as possible, any jars, tremors or concussions which would tend to injure the new work. The removal of the old brickwork is also required to be done without the aid or use of cofferdams or explosives, and to interfere as little as possible with navigation in the river.

INJECTING WATER INTO CRUDE-OIL ENGINES has been known for some time to result in great advantage to the economical operation of such engines and also to increase the power obtainable from a cylinder of given size when the water is supplied in addition to the oil into the vaporizer and cylinder. It is well established that with water injection much higher compressions are possible without danger of pre-ignition. The claim is also made that water injection lowers the temperature during the suction stroke and thus increases the charge drawn in. The increased efficiency of this type of engines with water injection is held by Mr. Robert F. McKay in a discussion of the subject in Engineering to be attributable to the chemical reaction which takes place between the carbon residue and steam at the very high temperature to which they are subjected.

Investigation of the Thermal Conductivity of Concrete and the Effect of Heat Upon Its Strength and Elastic Properties.

A paper read before the American Society for Testing Materials, by Prof. Ira. A. Woolson.

This paper is a record of some experiments made in continuation of work described in a previous paper before the American Society for Testing Materials. That paper recorded a series of tests showing that both the strength and elasticity of concrete were rapidly diminished by the application of comparatively low heat for moderate periods of time. The results appeared quite contradictory to well-established evidence regarding the behavior of that material in actual fires, and in fire tests of full size floor units. Endeavoring to elucidate this discrepancy, the writer made a single experiment on the conductivity of concrete which apparently explained the whole variation, and pointed to the fact that the virtue of concrete as a fire-resisting material was due to its high non-conductivity. The other tests showed that if it were thoroughly heated to 1,500° Fahr. its strength and elasticity were largely dissipated.

In the discussion which followed the reading of the paper it was suggested that further investigation of the conductivity of concrete should be made; also, that additional proof of the other results, using larger specimens and different concrete mixtures, was desirable. At the request of the Joint Committee on Concrete, the writer has continued the experiments and this paper is a summary of the new data.

The actual work of preparing and testing the specimens, making the calculations, and plotting the curves was done by students in the Department of Mechanical Engineering, Columbia University, under the writer's direction. This year the investigation was made by Messrs. R. M. Olyphant, Jr., Geo. W. Riddle and W. Putnam, students in the senior class, who did the work as a thesis problem. Their hearty co-operation and faithful attention to detail has alone made this paper possible.

The composition used was the same as last year, namely, a 1-2-4 mixture of Portland cement, sharp sand and ¾-in. clean broken stone, both trap rock and limestone being employed. In addition to these, other specimens were made in the same proportions, using clean ½-in. quartz gravel instead of the broken stone, and in another set, clean boiler cinders instead of stone. The cement was furnished by the committee and was said to be composed of a mixture of Giant, Lehigh and Vulcanite. It was a slow-setting cement, taking 7 hr. and 40 min. for initial set, and 14 hr. 10 min. for hard set. The average strength neat for 1 day was 246 lb.; 7 days was 710 lb. Mixed with three parts sand, the average for 7 days was 160 lb., and for 28 days, 286 lb. The concrete was mixed moderately wet and well tamped. The specimens were left in the molds 36 hr., then removed and submerged in water for 7 days, after which they were allowed to stand for 7 weeks in a cellar, being occasionally sprinkled.

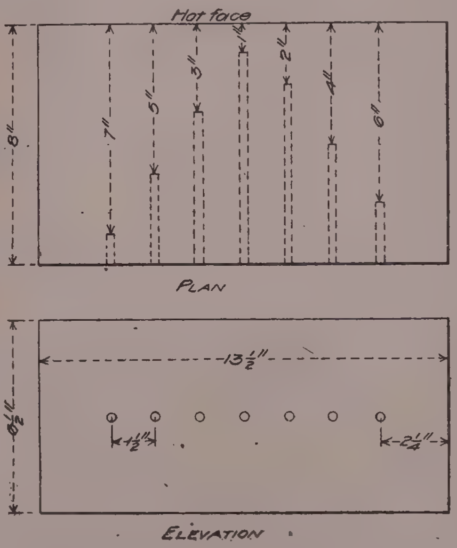
It was suggested that instead of raising the temperature of the specimens very slowly, so that three or four hours were consumed in attaining a furnace temperature of 1,500 to 2,000° Fahr., as was done last year, it would be instructive to bring the furnace temperature rapidly up to some fixed point, then holding it there for a definite period, the idea being that duplicate tests would be easier and the conditions approach more nearly those of an actual fire. This was done in all cases in the present series of experiments; 1,500° Fahr. was adopted as a fair average, and the furnace raised to that temperature in 40 to 60 min. and held there for the balance of the test. It was thought unwise to raise the temperature faster than this for fear of producing internal stresses that might rupture the specimens. In one instance the furnace did not work properly and the necessary heat was not secured in an hour. Three sizes of specimens were made: 4-in. cubes, 7-in. cubes and 6-in.x6-in.x14-in. prisms. The latter were used for measuring the elastic properties. The 4-in. cubes were made for comparing the strength of the new concrete with that of last year.

Method of Heating.—The specimens were heated in an oven-type of gas furnace. Those placed entirely inside the furnace were protected from the direct impact of the flames on the sides by shields of fire brick or clay tiles. This was done to insure as nearly as possible an even distribution of heat throughout the whole specimen.

Three and five hours were chosen for the times of heating the large specimens, and two and three hours for the 4-in. cubes. It was estimated that the internal temperature of the small specimens in that time would be about the same as that of the large specimens exposed the longer time. These time periods include that required for the furnace to reach 1,500° Fahr. After heating, the specimens were removed from the furnace and allowed to cool slowly in air.

The temperatures were measured by a carefully standardized Le Chatelier pyrometer, readings being taken simultaneously every ten minutes upon the thermocouple placed between the specimens, which registered the temperature of the furnace, and upon those embedded in the specimens which gave the corresponding internal temperatures at the points taken.

The specimens used to measure the conductivity by heating upon one side only were placed in the doorway of the furnace with the exposed face on a line with the furnace wall. These specimens completely filled the doorway with the exception of an inch at the top which was filled with magnesite board. An accompanying sketch shows the arrangement of large specimens in the furnace and in doorway.



Arrangement of Holes for Thermo-Couples.

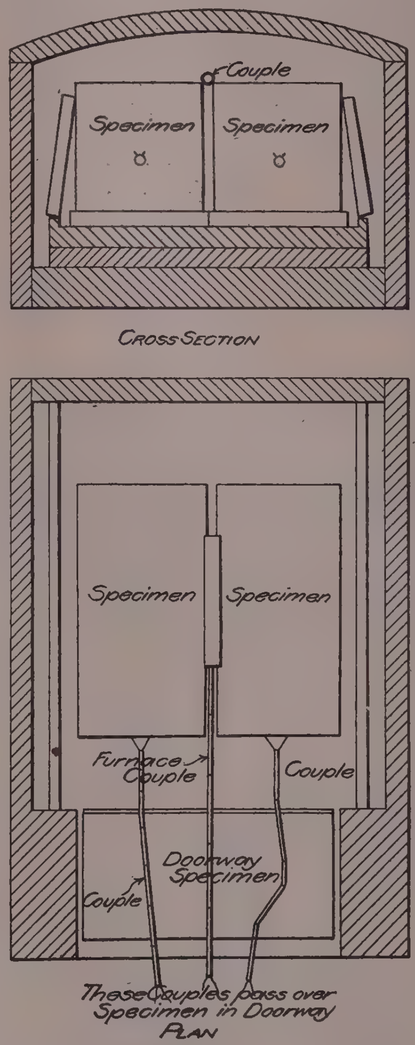
Specimens designed for strength tests were faced with plaster of paris before testing.

A few tests were made upon some specimens left over from last year's experiments, and two or three upon some samples of 1-2-3 trap rock mixtures two years old.

Classification of Specimens.

Lot A..........	1-2-4 mixture, limestone,	age 2 months.
Lot B..........	1-2-4 mixture, trap rock,	age 2 months.
Lot C..........	1-2-4 mixture, cinder,	age 2 months.
Lot D..........	1-2-4 mixture, gravel,	age 2 months.
Lot E..........	1-2-4 mixture, limestone,	age 1 year.
Lot F..........	1-2-4 mixture, trap trap,	age 1 year.
Lot H..........	1-2-4 mixture, trap rock,	age 1 year.
Lot K..........	1-2-3 mixture, trap rock,	age 2 years.

Conductivity Tests.—Most of the specimens used in this investigation were 7-in. cubes, this being as large as the furnace would take. A few were 6x6x14-in. prisms. When these specimens were made, thermocouples were cast in them at varying distances from the surface, the idea being that when these were tested in the furnace and temperature readings taken simultaneously upon the furnace atmosphere, and the couples embedded at varying depths in the concrete, the rate of transmission of heat through the concrete would be obtained. The work was carefully done, but results were confusing, and subsequent breaking of the specimens showed that the couples had been shifted by tamping the concrete when the specimens were made. In some cases they were an inch out of place and this completely nullified the work in regard to obtaining a rate of transmission from these specimens. Diagrams 2 to 5 are the curves plotted from these tests for a period of five hours in each instance. One curve gives the temperature of the furnace, which was brought up to 1,500° Fahr. in less than an hour and held there for the balance of the test, and the other curves show the corresponding temperatures on the interior of the specimens. Although the depths given to the couples are not entirely reliable for reasons already explained, nevertheless the curves are very interesting in showing the general lag in the rise of temperature in the specimen as compared with the furnace temperature.



Large Specimens in Furnace and in Doorway.

The gravel specimens were the only ones which attained an interior temperature equal to the furnace temperature.

It is rather surprising to note that cinder came next to the gravel in the amount of interior heat recorded, for cinder concrete is well known to be an effective fire resistant. However, the cinder concrete specimen, tested in the furnace doorway, gave the lowest interior heat. It was found impossible with the small furnace employed to maintain an even distribution of heat, and undoubtedly some of the conflicting testimony of the tests was attributable to this cause.

The curves in Diagram 5 are from tests of specimens one and two years old, and although the furnace worked badly, thus giving a very slow temperature rise, there is no evidence that either specimen possessed heat-resisting qualities superior to those of the new concretes.

Attention is called to one peculiar characteristic in all the curves. This is the flattening out at or a little after 212° Fahr. is past, showing that after steam begins to generate there is little if any rise in temperature until all the water in the concrete has been evaporated. The only curve in which this peculiarity is absent is K1, Diagram 5, and this specimen was two years old; it had been kept in a very dry room for over a year, and probably contained very little moisture. This was the only specimen available at this age and unfortunately it was tested when the furnace worked badly, so the results are not conclusive.

After ascertaining that the locations of the thermocouples in the above-described specimens were not all exact, one special trap rock block was made having seven holes ¼ in. in diameter cored in as shown in an accompanying sketch. The bottoms of the holes were arranged from 1 to 7 in. from the face to be exposed to heat, and the holes were spaced 1½ in. apart. Thermocouples were sealed in these holes and all connected through a switchboard to the same galvanometer. The position of these thermocouples was absolutely assured.

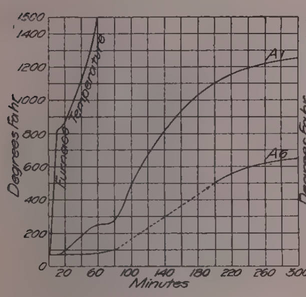


Diagram 1.

Limestone, 2 months old.
A-1. Specimen in furnace, temperature measured 3 in. from face.
A-6. Specimen in doorway, temperature measured 4.5 in. from face.

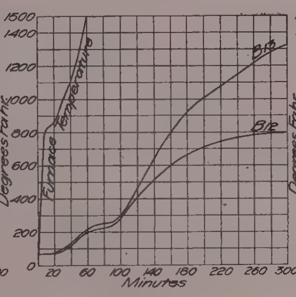


Diagram 2.

Trap Rock, 2 months old.
B-13. Specimen in furnace, temperature measured 1 in. from face.
B-12. Specimen in doorway, temperature measured 1.5 in. from face.

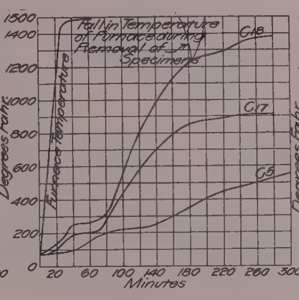


Diagram 3.

Cinder, 2 months old.
C-18. Specimen in furnace, temperature measured 2 in. from face.
C-17. Specimen in furnace, temperature measured 3 in. from face.
C-5. Specimen in doorway, temperature measured 1.5 in from face.

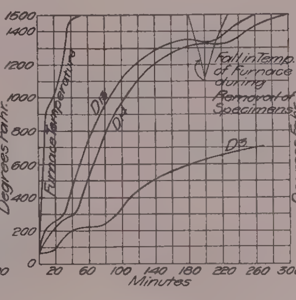


Diagram 4.

Gravel, 2 months old.
D-13. Specimen in furnace, temperature measured 2 in. from face.
D-14. Specimen in furnace, temperature measured 3 in. from face.
D-3. Specimen in doorway, temperature measured 4.5 in. from face.

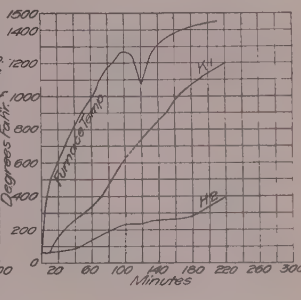


Diagram 5.

Trap Rock, 2 years old.
K-1. Specimen in furnace, temperature measured 1.5 in. from face.
K-2. Specimen in doorway, temperature measured 4.5 in. from face.

Temperature Rise at Different Points in Limestone, Trap, Cinder and Gravel Concretes, all 1:2:4 Mixtures.

This specimen was placed in the furnace doorway and subjected to 1,500° Fahr. on one face for five hours. Readings were taken every ten minutes on each thermocouple, and the results are shown in the plotted temperature curves in Diagram 7. These curves are very instructive although there is some interference. The first salient characteristic of them all is the lag at the 212° point. It will be noted that this is greater with increased thickness of the concrete; also that up to 3 in. thickness the recorded temperature at which it occurs is above 212°, showing that the surface of the concrete heated very rapidly and went above the boiling point of water. It is undoubtedly these conditions which cause steam to generate rapidly enough to become explosive and burst off patches of concrete, which is a common occurrence in fire tests.

The curves for the points 1 in. and 2 in. from the heated face are nearly the same. The indications are that they would have been run together had the test continued longer. The reason for this is not apparent, but it may have been due to an accidental arrangement of the stone in the concrete in such a way as to form a comparatively solid stone connection between the thermocouples, which by its better conducting qualities tended to equalize the temperature between the points.

Considering these two curves as one, there is a marked parallelism between it and the curves embedded 3, 4 and 5 in. in the concrete, and the distance between them is very constant. The curves for 6 and 7-in. points are irregular, although No. 7 is nearly parallel with the others. No. 6 is particularly freakish. The reason for this is plain. Points No. 6 and 7 were 2¼ in. from the end of the block, and as these ends were more or less heated from the furnace walls, the points in question received some heat from this source as well as the face. This threw their temperature curves out of harmony with the central points which were not so affected.

As a whole, they are regular and indicate that the heat-resisting quality is not a direct function of the distance from the heated surface to interior point at which the temperatures were measured. It will be noted that the curves flatten out and that doubling the distance more than doubled the time required to secure the same temperature rise.

These curves as well as those of Diagrams 1 to 5 show conclusively that the very low thermal conductivity of concrete indicated by the single test reported in our paper of last year was entirely correct. They prove that two or three inches of concrete properly mixed, tamped and set, will resist a fierce conflagration for hours without permitting a serious temperature rise upon the opposite side.

Strength and Elasticity Tests.—Table I gives the results of tests upon the 4-in. cubes. In the one-year-old specimens (E and F) comparison is given with tests of duplicates made when they were one month old. The increase in strength is not large. Both the limestone and trap specimens made this year are much stronger than those made a year ago. The probable explanation is that the specimens were soaked in water this year for one week on removal from the molds, and last year were only sprinkled. It is doubtful if they then received sufficient water to produce a perfect set of the cement.

It will be noted that specimens A and B when heated 3 hours at 1,500° Fahr., were stronger than those heated two hours. This is contrary to all our previous experience and must be attributed to one of two causes: either the specimens heated two hours happened to be weak structurally, or the three-hour specimens were protected in some way in the furnace and did not get the heat credited to them. In any event the results are anomalous and should be rejected.

Table I.

Crushing Strength of Concrete Before and After Heating.

Lot Material.	Breaking Loads, Lb. Per Sq. In. Not Heated.	Same lot in 1905 when 1 mo. old.	After heating 2 hrs. at 1,500° F.	After heating 3 hrs. at 1,500° F.	After heating 5 hrs. at 1,500° F.
	4 x 4 x 4-in. specimens.				
A Limestone....	3,030	....	980	1,445	
B Trap Rock...	3,195	....	1,300	1,410	
C Cinder.......	1,360	....	750	447	
D Gravel	2,740				
E Limestone, 1 year old....	1,741	1,968	1,235	937	
	2,165	1,843	1,110	906	
		1,640	1,200		
			1,290		
F Trap Rock, 1 year old....	2,230	1,903	1,525	665	
	2,800	1,913	....	695	
	2,240	1,982	....	.....	4 hrs.
K 6-in. cube limestone 2 yrs. old	2,290	....	....	....	2,005
	6 x 6 x 14-in. specimens.				
A	2,740	....	....	1,345	870
B	3,140	....	....	1,400	997
C	1,400	....	....	547	504
D	2,780				

Note.—Where more than one breaking load is given it indicates that several specimens were tested.

Table II.

Elastic Properties of 6 x 6 x 14-in. Prisms.

Lot Material	E at 200 lb. per sq. in. Unheated.	Heated 3 hr.	Heated 5 hr.	E at 400 lb. per sq. in. Unheated.	Heated 2 hr.	Heated 5 hr.	E at 800 lb. per sq. in. Unheated.	Heated 3 hr.
A Limestone..........	6,000,000	200,000	....	6,000,000	285,000	....	5.647,000	425,000
B Trap Rock........	3,430,000	150,000	129,000	4,355,000	222,000	188,000	4,355,000	348,000
C Cinder	1,090,000	49,500	57,100	960,000	....	....	915,000	....
D Gravel	8,000,000	....	....	6,887,000	....	....	6,000,000	....

Blank spaces indicate that specimens had failed by fire or crushing.

Table III.

Elastic Properties of 6 x 6 x 14-in. Prisms Heated on One Face Only.

Lot Material.	Modulus of Rupture (E) after heating 5 hr. At 200 lb. per sq. in.	At 400 lb. per sq. in.	At 800 lb. per sq. in.	Breaking Load. Lb. per sq. in.
A Limestone....................	293,400	521,700	730,700	1,840
B Trap Rock....................	200,000	268,000	379,000	1,705

No strength tests were made upon heated gravel specimens because they all either fell in pieces upon removal from the furnace or were so badly cracked as to prohibit testing them.

Table II gives the modulus of elasticity (E) calculated on increasing loads for specimens that had been heated for different times. Usually the moduli of unheated specimens decreases with increase of load, but it is not infrequent that they reverse the rule; the exception is in evidence in this series. The moduli of the heated specimens are very low in value, but in all cases the value increases with increase of load. This peculiarity was referred to last year. The reason is not clear, but perhaps it is because the specimen expanded on heating, and when cooling, the outside contracts more rapidly, thus developing many fine cracks which do not entirely close when normal temperature is reached. The first loads applied to the specimen serve merely to close these cracks and the compression observed is not, therefore, the true deformation of the concrete for these pressures. The value of the moduli decreases very rapidly with increase of heat treatment. This fact was also brought out last year; the present figures are merely confirmatory.

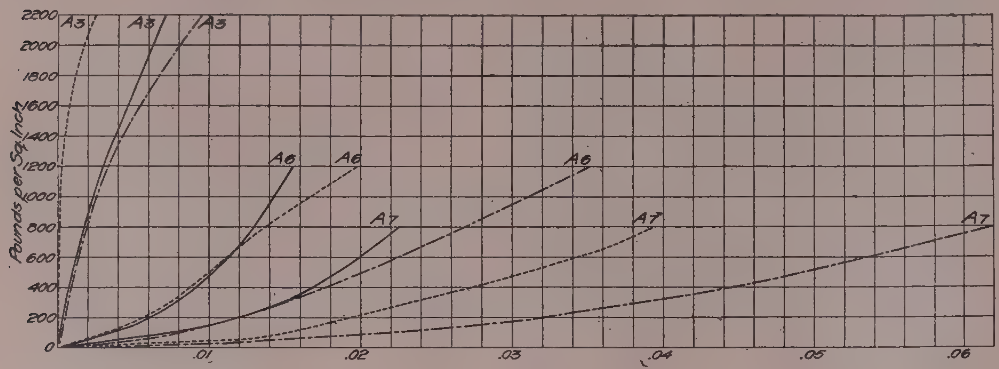


Diagram 6. Elastic Curves of 6x6x14 in. Specimens.

Dot-and-dash line, total compression; Dotted line, permanent set; Full line, elastic compression; Curves A-3, unheated specimen; A-7, specimen heated 3 hr. in furnace; A-6, specimen heated 5 hr. in doorway.

The limestone lost about 50 per cent. of its strength when heated 2 hours, and the trap about 55 per cent. The difference was undoubtedly accidental, for we well know that trap is superior to limestone in resisting heat. They both lost 68 per cent. of their strength in 5 hours, when heated on all sides with no radiation permissible.

The strength of the 6x6x14-in. specimens heated on one face, see Table III., is in marked contrast to those heated on all sides, and shows that under that condition the concrete retains a large part of its strength even after five hours of exposure to a temperature of 1,500° Fahr. As a matter of fact the specimens tested in this manner really received considerable heat upon four other faces, for it was impossible to protect them from the radiant heat from the furnace walls, so they were probably heated more thoroughly than they would have been had they formed a part of a concrete wall facing the fire.

Diagram 6 gives a specimen sheet of the elastic curves obtained from the 6x6x14-in. specimens both before and after heat treatment. Three curves are plotted for each test: (1) total deflection, (2) set, (3) true elastic; the last being obtained by subtracting the second from the first. (Negative sets were in evidence in these curves, though not so pronounced as in some previous tests.) The prominent feature of the curves is the great increase in deformation with loss of strength due to heat treatment. The elastic curves of the specimens which were one and two years old, respectively, do not, apparently, show any material increase in their fire-resisting qualities, although these specimens were heated only 4 hr. Diagram 8 gives the true elastic curves, grouped according to treatment, without regard to the total deflections from which they were derived.

The marked difference in the strength of the specimens made last year and this year, in which the same stone was used, and presumably an equal quality of cement, show that the treatment during the period of setting has much to do with the quality of the concrete. It would be interesting to ascertain if the fire-resisting properties are influenced by the amount of moisture absorbed by the concrete while setting is taking place.

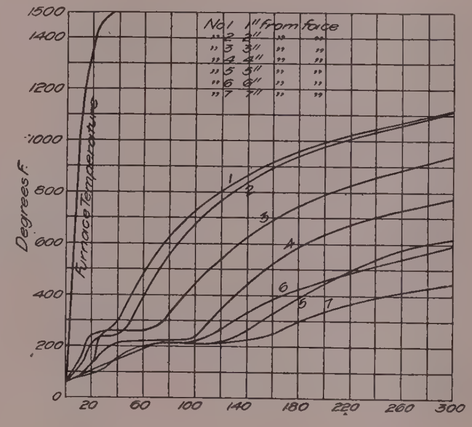


Diagram 7. Temperature Curves.

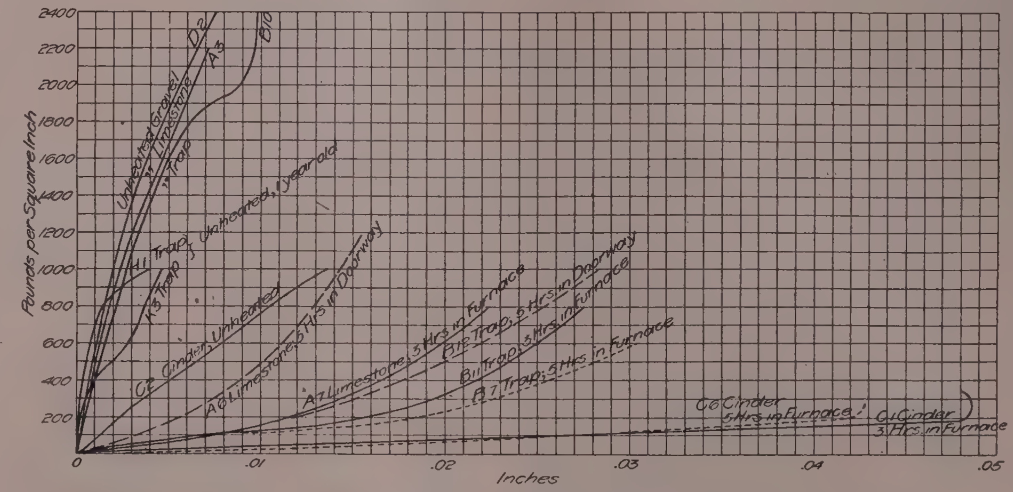


Diagram 8. Curves of Elastic Compression Grouped According to Treatment.

It is fully recognized that definite conclusions cannot be drawn from tests so incomplete as these; but they serve to point the way and it is hoped that more elaborate experiments may be made which will furnish the additional evidence necessary.

RECOVERING LOST DRILL POINTS with electromagnets has been accomplished successfully in various places in Pennsylvania. At Greensburg a heavy point stuck at a depth of 250 ft. in a well but was readily loosened and brought to the surface with an eletromagnet.

New Public Service Building at Milwaukee, Wis.

The Milwaukee Electric Railway & Light Co. has recently completed an extensive combined office building and interurban railway terminal station which is interesting and unusual not only on account of its size and architectural treatment. but also as it provides for all of the offices of the company, has a terminal station with all the requirements for passengers, contains machine shops, physical and chemical laboratories, a convention hall, dining-rooms, and when fully completed a 4,500-kw. generating plant will be installed in the basement. It has been termed the Public Service Building, as it is the headquarters in Milwaukee for the electric lighting, public heating and transportation services which are supplied by this company.

The building occupies the entire block bounded by Sycamore, Second, Third and Everett Streets, and is 200 ft. x 300 ft. in plan. It is of steel skeleton construction, with columns encased in concrete and resting on concrete footings which are carried on piles. The building is at present four stories high, but provision has been made in the design of the columns and the manner in which they are carried through the roof for an increase of height to eight stories whenever the growth of the company's business demands. The basement and the first floor of the building cover the entire ground plan, but the three upper stories are broken by three light courts, 20 ft. wide, on the rear, which divide the rear of the building into four wings.

The exterior of the building is shown in one of the accompanying illustrations. The first story, the trimmings and cornice are of Bedford stone, while the main body is faced with warm gray Norman brick. The appearance of the structure as a whole is enhanced by hammered copper cresting which surmounts the cornice. The main facade on Sycamore St. is flanked by two pavilions carrying ornamental balustrades and canopies. This facade is further ornamented by the carved stone work carried up to the third story about the main entrance, midway between the two pavilions.

The rotunda, just inside the main entrance, which is carried up two stories and finished entirely in marble, is the most ornate portion of the building. The walls, which are of the lighter shades of Sienna marble, obtained from an old convent quarry in Italy, are enriched by a frieze of panels of Swiss Cipilino. The main entablature and balustrade surrounding the rotunda at the second floor level are carried by a series of Doric columns of white Italian marble. In the second story, immediately above, are an equal number of Ionic columns of similar marble. The ceiling of the rotunda is highly ornamented with stucco, and from its center will be suspended a large electric chandelier of attractive design. In the main entrance to the left of the entering doors are the two elevator shafts, which are provided with grills of Tiffany bronze.

Directly opposite the entrance doors is the main stairway, which, branching in opposite directions at an intermediate landing, reaches the second floor near the entrance of the theatre on one side and at the entrance to the auditing department and the club quarters of the company's employees on the other. This stairway and that reaching the third floor are provided with a balustrade of white Italian marble, while the treads and risers are of Joliet limestone. A narrower stairway, reaching the fourth or top floor, is provided with a balustrade of Tiffany bronze of a very ornamental design.

The floors of all the corridors above the first story consist of slabs of Joliet and Godfrey gray limestone with borders of rouge royal and dark Tennessee marbles. The walls of the corridors on the second and third floors are finished with a wainscoting of white Italian marble, while the finish of the fourth-floor corridors is in light gray Tennessee marble. The interior woodwork of the entire building is of birch, except in the suite of the president and general manager, which is paneled of fumed oak, and the directors' room, which is finished in solid mahogany. The desks, tables, and practically all the furniture in the building are of the same material as the interior finish.

Exterior View of the Milwaukee Public Service Building.

Unusual attention was given to the problem of lighting, both natural and artificial, and the building is a good example of the latest developments in illuminating engineering. The light courts already referred to and the general arrangement of the rooms obviate the use of artificial light during the day in all parts of the building with the exception of the basement and a few closets. Artificial lighting is by electricity alone, and quite a series of tests were conducted by Mr. O. M. Rau, superintendent of the electric lighting department, and his assistant, Mr. F. A. Vaughn, electrical engineer of this department, in order to arrive at the most suitable methods. The method finally decided on is that of providing an even distribution of light rather than concentrating lights in central chandeliers. With very few exceptions all portions of the building are lighted by individual incandescent lamps suspended about 3 ft. from the ceiling by brass electroliers. These electroliers are fitted with the new General Electric metallized filament lamps of 50, 75 and 100 candle-power, the intense glare of the filament being destroyed by frosting the lower portion of the bulb. Each of the electroliers is fitted with either a class C or a class D Holophane reflector, the former over desks where a concentration of light is desired, and the latter where general diffusion is wanted. The lighting of all the offices was figured out on a basis of 2 candle feet at the desks, and practically the same basis was used in the lighting of the corridors, toilet rooms and other portions of the building. In several portions, for example, the theatre and the directors' room, an ornamental effect rather than equal distribution was desired, and pleasing modifications of the general lighting scheme were followed.

Practically all the ground floor of the building is devoted to a central car house and terminal station for the interurban and suburban lines of the railway department. The front portion east of the entrance, however, is used by the electric lighting department as a salesroom and display room, is fitted with marble counters, and is provided with closed cabinets in which supplies are kept. The public waiting room, just west of the main entrance, is finished in Tennessee marble and has in connection with it a retiring room for ladies. The waiting room opens directly into the car sheds, which extend the full length of the building and have six tracks connecting with the car tracks on Second and Third Sts. The repair sheds, which are separated from the car sheds by a brick dividing wall, contain five similar tracks.

The floors of both of the car shed compartments are of reinforced concrete, while the pits under the two southernmost tracks in the car sheds and also under four of the tracks in the repair shop are of concrete construction, and slope to a drain at one end connected with the sewer. The pits, moreover, are heated by pipe coils along one side and are lighted by incandescent lights wired in iron conduits. The lights are placed in recesses in the cement just under the rail, these recesses being so shaped that the walls act as reflectors for the lamps. The space along the rear wall of the repair shop will be utilized for the few machine tools required and by the emergency repair crews. Only the washing and cleaning, oiling and light repairs will be done in this shop; for general repairs the cars will be sent to the central shops of the company. The car sheds are well lighted, the bottoms of the light courts above being provided with skylights of the usual type. Artificial light is supplied by individual incandescent lamps supported a few feet from the ceiling by brass electroliers.

One of the most interesting features of the car sheds is the type of door closing the opening through which the cars enter the building, which doors were designed by Mr. E. W. Olds, superintendent of rolling stock of the railway department. They are double and hinged together in the usual manner, but the door as a whole is hung on a 4-in. gas pipe which projects down into the floor and up into the concrete construction above and is supported on roller bearings. A steel framework bolted securely to the gas pipe carries the door proper. This construction prevents the door twisting and adds to its strength. The upper portion of the door is provided with glass fitted in metal sash.

A stairway from the car house leads to the trainmen's quarters on the floor above, which rooms are adjacent to the offices of the superintendent of transportation, in the northwest corner of the second floor. The headquarters of the division foremen, to whom the trainmen report, is provided with a counter and windows for each foreman. Behind this room is another provided with desks fitted with glass compartments and used by the trainmen when making out reports. A gallery above and a portion of the main floor in an adjacent room contain about 300 metal lockers for the use of trainmen, and toilet rooms of ample size are located on the opposite side of the corridor.

The auditing and accounting department occupies the east half of the front portion of the building and also the east rear wing, on the second floor. For almost the full length of the front room is a counter of St. Anne Italian marble, surmounted by a lacquered brass grill behind which the office force is located.

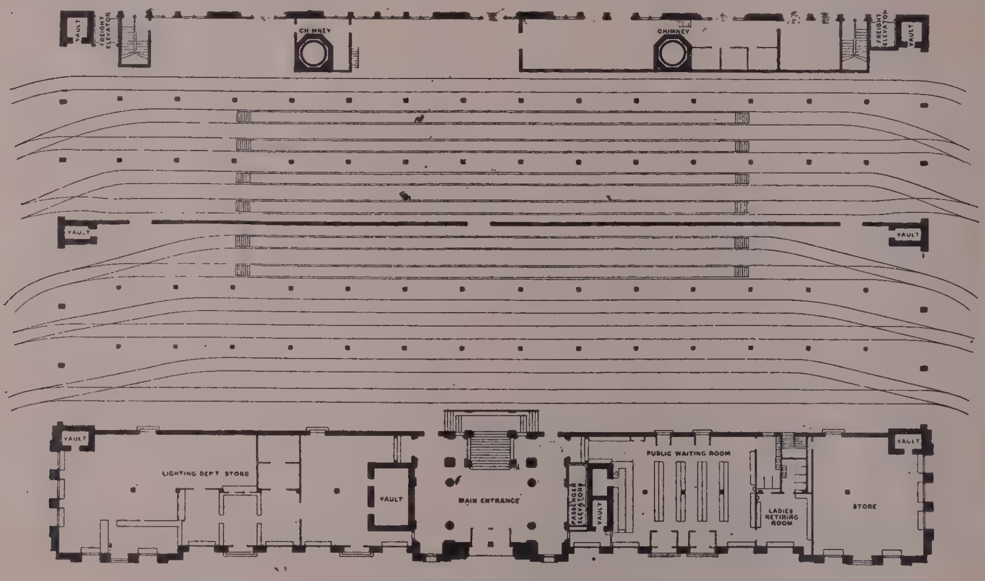
It was the intention that the building should serve as a social centre for all of the employees, and to this end club quarters were provided. These rooms take up all of the east central wing to the rear of the second floor. A corridor down the middle of this wing leads to the library in the rear, while about midway of its length is a small rotunda with doors opening into the dining-rooms, barber shop, and billiard rooms. Two dining-rooms are provided, with a kitchen equipped with facilities for cooking both by electricity and by gas and with refrigeration from an ice machine in the basement. At one end of the library in the rear is a large fireplace, while directly opposite is an enclosure fitted with metal book shelves. In addition to reading matter of a general nature, the library will be well supplied with technical books and journals. The bowling alleys, which are included in the club quarters, are located in the east half of the west wing. A medical department occupies five rooms on the third floor.

The convention hall occupies the entire second and third floors of the west central wing. The hall has a total seating capacity of about 1,200 people, has a stage as fully equipped as that of a modern theatre. The asbestos drop curtain with which it is supplied and the several other curtains in use are raised by motors.

The west wing of the third floor contains the offices of Mr. C. J. Davidson, chief engineer; of Mr. Fred G. Simmons, superintendent of way, and of Mr. E. W. Olds, superintendent of rolling stock. Across the corridor from the office of the chief engineer are the laboratories belonging to the mechanical engineering department, which, when finished, will contain machines for testing concrete, oils, coal and other materials used by the company. In the rear of the laboratories is the general draughting room for all the departments.

The electric lighting department is located on the third floor in the eastern portion of the building, embracing in the northeast corner offices of the superintendent of this department, and also of the electrical engineering department. The large room next to the central corridor of the building is used as a working office by this department and by the meter department. The publicity department also has its quarters in this room.

The testing department contains, among other apparatus, quite an elaborate testing board. One side of this board, which consists of a high panel carrying instruments and switches with a bench on either side, is used for testing of a general nature, while the other side is utilized for testing meters alone. One end of the board has facilities for testing the telephone apparatus, including that of the automatic telephones. The testing department will also be supplied with a six-phase motor generator set from which different frequencies and phases of current may be obtained, while a separate room has been reserved for photometric tests. Just north of the test room is a shop which is devoted largely to the manufacture of switchboards and electrical apparatus. This shop contains a full equipment of machine tools, including turret lathes, milling machines, drill pressers and grinders. In the basement is installed a large radial drill belonging to the shop equipment, which is used exclusively for boring switchboard panels. All of the separate tools in the shop have individual motor drive, the motors in most instances being mounted on the machines.



Plan of the Waiting Room and Car Sheds on First Floor.

At the rear of the test room is the installation and repair department, and opening from the large central room devoted to general work are several small ones used for different purposes. One of these contains electrically driven arc light globe washers and electro-magnetic carbon cutters. Another is equipped with several grinders and buffers used in finishing switchboard and other brass and copper work. This room is provided with an exhaust fan having tubes running to each machine. Near the rear of the building is a locker and toilet room for the employees in the shop. A freight elevator in the southeast corner of the building handles all heavy work going into and out of the shop, as well as electric meters.

The offices of president and general manager, Mr. John I. Beggs, in the northwest corner on the fourth floor, are the most elaborately finished rooms in the building. The president's suite of offices consists of a reception room, a main office in the corner of the building, a private office to the east with a bathroom opening off from it, and a private secretary's room west of the main office. The walls of all these rooms are paneled to the ceiling in fumed oak, while the door casings are hand carved. The ceiling is deeply paneled in stucco ornamented with gold leaf. The floors are of hardwood with a border of parquetry. The furniture, which consists of davenports and chairs upholstered in Spanish leather, book cases and desks, are of oak to match the general finish of the room. A feature of the room is the fireplace and mantel against the south wall of the room, of marble and bronze with heavy fluted brass andirons.

With the exception of the storeroom of the lighting department, located in the southern end, the greater portion of the basement is taken up by a power plant, elevator machinery, air compressors and refrigerating machines. A contract for furnishing steam to the Milwaukee Central Heating Co. was primarily responsible for the installation of the power plant, which when completed will consist of ten 500-kw. Edgemoor boilers and three 1,500-kw. Allis-Chalmers Parsons steam turbines. The limited amount of space available introduced several difficulties in the installation of the boilers, which are arranged in one row near the south wall of the building. Although of 500-h.p. capacity, each boiler is installed in a space 12 ft. 9 in. high and 16 ft. 5 in. wide. An idea of the close work required to get the boiler in the space available may be obtained from the accompanying drawing showing the boiler installation. The boiler itself was designed by the late Mr. William Sellen, while the setting, which includes the side tubes, was devised by Mr. C. J. Davidson, chief engineer.

The boiler consists of a skeleton of tubes supported on legs connected by water tubes. These water tubes are provided with a fire-brick covering, and similar bricks enclose the tubes of the boiler proper. The lower tubes, together with the fire brick enclosing them, might be said to form the boiler setting, and consequently the space taken up by the usual brick furnace walls is saved. The limited head room made the use of a steam drum out of the question, and the steam is taken directly from the rear header of the boiler and only about 15 in. above the water level. Immediately in front of the line of boilers and projecting out under the sidewalk is a space for coal storage, the coal being dumped in through sidewalk coal holes above. Two stacks built of blast-furnace slag, each 150 ft. high and 9 ft. in diameter, serve the boilers. The stacks project up through the building, and special construction was carried out to lessen the heat radiation. Each is enclosed in a brick well with air space between, the stack proper and the enclosing well allowing for difference in the expansion and contraction entirely independent of each other. The boilers are fed by two Worthington 14-in. x 8½-in. x 15-in. centre-packed piston plunger pumps installed in connection with two 1,500-h.p. Hoppes heaters.

As power could be obtained at a comparatively low cost by passing the steam through engines before turning it into the heating mains leaving the building, the three 1,500-kw. turbines already mentioned will be installed in the central portion of the building. These turbines are of special design to operate non-condensing, and will, in fact, operate with a back pressure of 7 lb. With this pressure, which is equivalent to 22 lb. absolute back pressure, and with 150 lb. pressure at the throttle, these turbines have a guaranteed consumption of 44 lb. of dry steam per kilowatt-hour at three-fourths load, 40 lb. at full load, and 41 lb. at one-fourth overload. The generators driven by the turbines are of the Bullock type, 2,300-volt, 60-cycle, three-phase, with an exciter mounted on the same shaft. Part of the alternating-current generated will be sent out of the station without transformation, but the greater portion of it will be supplied through two 1,500-kw. motor-generator sets to a direct-current Edison system feeding the business district of the city. A storage battery is installed in the basement and floats on the Edison system. It consists of 320 G-39 chloride cells, and is provided with end-cell switches and connections. Space has been left near the centre of the building for another battery of twice this size when the growth of the system demands. In connection with the battery there is installed a 150-kw. booster set. The switchboard for all the electrical apparatus in the basement and also for lighting the building is located under the Sycamore St. side of the walk.

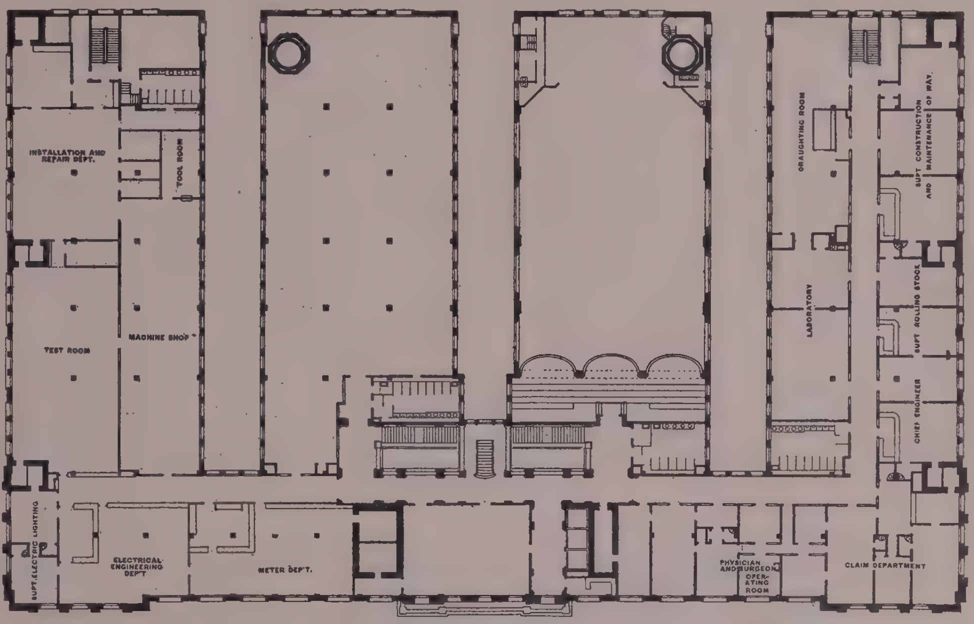
Interior of Main Entrance.

The boilers in the basement and the turbines will only be operated during the winter season when steam is required in the heating mains. For furnishing a summer load on these, provision has been made for the installation of two 100-ton steam-driven ammonia refrigerating plants, it being the idea to furnish refrigeration to hotels, cafés and other places of business in the immediate district. At present one 28-ton Vilter Manufacturing Co.'s motor-driven ice machine is installed, which is used to cool the drinking water and to furnish refrigeration to the kitchen and the lunch counter in the waiting-room.

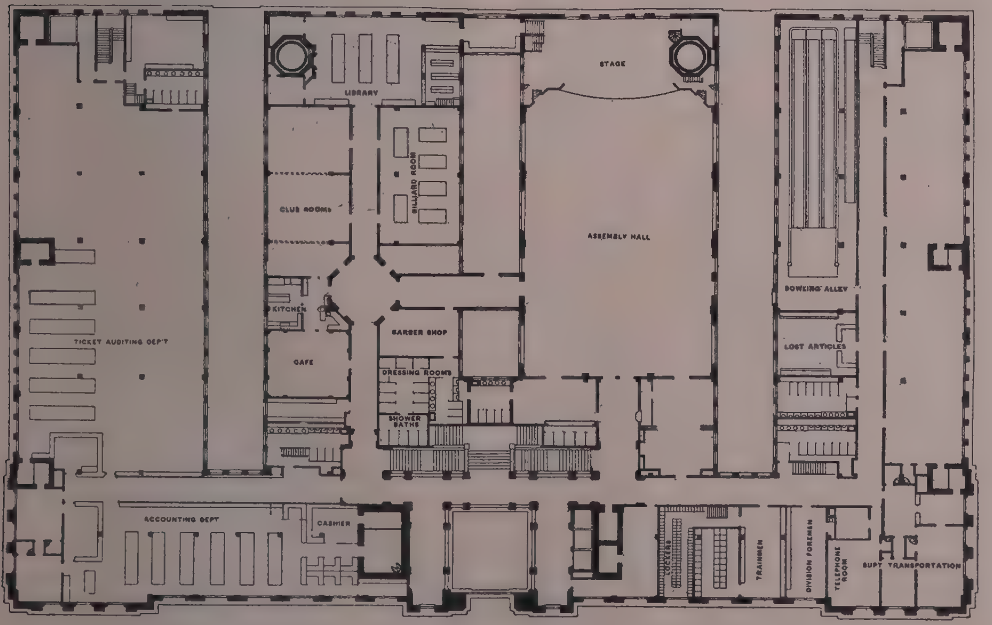
Two 150-ft. motor-driven Christensen air compressors installed near the ice machine, maintain a constant air pressure in four tanks near by for operating of the pneumatic tube system in the building, the pneumatic tools and the heat regulating system, and to open elevator doors. All the elevators are electrically driven, the machinery being located in the basement. Two drum-type electrically-driven passenger elevators having a speed of 600 ft. a minute are installed. They are operated by hoists manufactured by the Barth Manufacturing Co., and are built for 1,500 lb. load. Two freight elevators, one in each of the rear corners of the building, are built for 4,000 lb. and travel at 250 ft. per minute. In addition to the elevators mentioned there are also two sidewalk hoists and a hoist from the storeroom of the electric lighting department to the salesroom above. In the basement is also a shop for cutting, bending and threading pipe. All work of this nature for the entire system will be done in this shop, which is equipped with Bagnall & Keeler pipe machines, Baker tapping machines, and a pipe-bending machine.

The arrangement of the fireproof vaults with which each office is supplied is somewhat out of the ordinary. They occupy eight separate shafts which extend from the footings of the building to the roof. The shafts are provided with floors of concrete slabs and doors built by the Cary Safe Co. All of the book shelves and filing cases in the vaults are of metal.

Although the building is of fireproof construction, careful attention has been given to protection against local fires in any portion. Hose racks connected to standpipe lines are located at convenient points in the corridors and other places, and the car sheds, freight elevator shafts, and basement door openings are provided with automatic fire doors. The car sheds, store rooms, and the stage of the theatre are fitted with automatic sprinklers, a total of 2,000 Grinnell sprinkler heads having been installed in the building. These heads are all connected to tanks in the basement, each of 10,000 gal. capacity, in which the pressure of the city mains is maintained by a 6-in. electrically-driven two-stage centrifugal pump. A check valve keeps up the pressure in the storage tank in case the pressure in the city mains falls. In event of an emergency the storage tank just referred to may be connected to the two 10,000-gal. tanks used for the storage of spring water, and the contents of these may be discharged through the sprinkler system. The stand pipes are connected to the city system by two 6-in. mains which enter the building one at the east and one at the west end.



Plan of Third Floor of Milwaukee Public Service Building.



Plan of Second Floor Containing Offices, Club Rooms and Assembly Hall.

Drinking fountains distributed throughout the building are supplied with water from the Waukesha springs. The piping system by which the fountains are fed, centres in two concrete tanks in the basement, each of 10,000 gal. capacity. Water from the springs is hauled to the building in tank cars and is discharged from these into the tanks, and pumped through the building by two motor-driven centrifugal pumps. The water in the system is kept at a temperature of about 40 degrees by coils from the ice machine in the basement.

A cleaning system consisting of a system of piping extending to all parts of the building, and two steam aspirators in the basement for producing a vacuum in the pipe system is installed. The outlets are at such intervals that all portions of the building can be reached by hose of convenient length, and enough tools and apparatus are provided to keep twenty janitors at work. This system was installed by the American Air Cleaning Co., of Milwaukee.

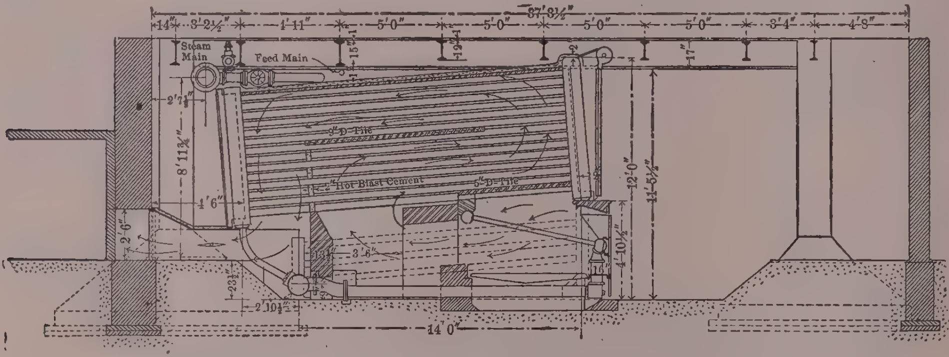
The provisions for telephone service in the building also received special attention. The Strowger automatic system is combined with the Bell system, a telephone room on the second floor containing an automatic exchange as well as a manual switchboard for the building and a despatcher's board. In an adjacent room is installed a storage battery with motor generator, used in connection with the telephone system, and a marble switchboard for all the low-voltage electrical apparatus in the building is installed in the partition between the rooms. There are at present about 100 telephones installed. Desk telephones of the Strowger automatic system are employed, but are fitted with Bell transmitters. Each telephone is provided with special connections which permit the use of the manual or of the automatic exchange at will. The manual board is interconnected with the despatcher's board, so that any of the offices may be given connection with the booths of the despatcher's system out on the interurban lines.

The transmission of mail reports and documents of various kinds between the different departments is facilitated by a Lamson pneumatic tube system which centres in a room on the second floor of the building and connects with twenty-one terminal heads in the various offices. The system is operated with compressed air from the storage tanks in the basement, and the electrically controlled valves are supplied with current from storage batteries in the telephone exchange room. Each of the carriers in which the papers are carried has printed upon it a directory of the offices in the building. When a document is to be transmitted to a distant department an indicator on the cartridge is turned to the number of that department as shown by the directory, and slips the carrier into the tube. It is received in the central tube room by an operator who sends it on to the department indicated. By means of this system a document can be sent to the most distant part of the building and can be signed and returned in about one minute.

In the several offices and corridors of the building there are about forty electric clocks installed, which are operated in synchronism with a master clock located in the telephone exchange room. One of the clocks, of ornamental design, is placed over the main entrance to the building, another is mounted over the main stairway from the first floor, while a third, of unique design, is located in the room of the private secretary to the president and general manager.

All the wiring for the lights, power, telephones, clocks, and pneumatic tube system is inclosed in iron conduits embedded in the concrete floors and carried between the separate floors in shafts. The wires to each floor are run to central switch board cabinets containing the switches for the lights and motors and the terminals for the low-voltage wires. The switchboards, which were built by the electric lighting department, are equipped with a combination fuse and switch which is so built that the enclosed fuses form the switch blades and thereby save the space usually taken up by the fuse bases. The switchboard in the basement contains a separate lighting panel for each floor of the building, and in addition one panel for the power circuits. The lighting panels are provided with both alternating and direct-current buses. Two feeders to each floor leave the separate lighting panels, one feeder going direct to a cabinet in the east end of the building, while the other reaches a cabinet in the opposite end. Other feeders connect the two cabinets with a third, forming a loop circuit, so that in the event of failure of one of the feeders, the other can be used to light the whole floor. The wiring also permits current from either the direct or alternating-current bus bars to be supplied to each separate floor.

In the design of the building, Mr. Herman J. Esser, of Milwaukee, was retained as architect. The entire design was, however, under the special supervision of Mr. John I. Beggs, president and general manager of the Milwaukee Electric Railway & Light Co. All details, even to the furniture, were submitted to Mr. Beggs and it is due to his personal interest that such successful results were secured.



Cross Section of Boiler Setting in Basement, Public Service Building.

THE TELTOW CANAL, which was recently opened for traffic, establishes an important connection between the eastern and western canal systems of Prussia and inaugurates in Europe electric traction for canal propulsion. The canal connects the Havel River near Potsdam with the Spree River above Berlin. It is 22.5 miles long, 64.6 ft. wide on the bottom and accommodates 600-ton barges. The canal cost $10,000,000, and was built by the municipality of Teltow. The towing system on it differs from any other in use in Europe, resembling to a certain extent the system that has been installed, although but little used, on the Miami and Erie Canal in Ohio, in that the latter also uses electric locomotives on double tracks. The Teltow locomotives each have two 8-h.-p. motors, one coupled to each of two axles. Electric power is generated at 6,600 volts alternating current in a 2,800-h.-p. steam turbine plant and transformed into 550-volt direct current with which the locomotives are fed from an ordinary overhead trolley. The locomotives are so designed as to prevent them being overturned by the lateral pull of the barges being towed. The method of attaching the tow line to the locomotives is also such as to permit a locomotive with a string of barges to pass a barge moored along the bank of the canal. The canal contains a double lock which has been provided with single gates that are raised and lowered in a vertical plane.

Experimental Methods as Applied to Water and Sewage-Works for Large Communities.

By Mr. George W. Fuller. One of several papers prepared in commemoration of the twenty-fifth anniversary of the doctorate of Prof. William T. Sedgwick.

That progress means advance in knowledge and the gradual transition of information from the unknown to the known is of course a truism. The manner by which progress is made in different lines of work varies widely. The experimental method as applied to the teaching of science in educational institutions has been of great benefit, and the application in a more systematic manner than formerly of the so-called "cut and try" method of the early inventors has resulted in more substantial progress in many mechanical and industrial lines. By the man of affairs this advance in knowledge is referred to as additional experience. It is not the purpose of this paper to attempt an analysis of the manner by which knowledge in general is advanced, but to refer somewhat briefly as a matter of record to the way in which there have been solved various sanitary problems which a quarter of a century ago, for financial or other reasons, seemed out of question.

It is fitting on this occasion that this topic should be touched upon, owing to the influence exerted upon this line of work by the two institutions with which Prof. Sedgwick has been most actively connected in recent years, viz., the Massachusetts State Board of Health and the Massachusetts Institute of Technology. The former has for years been the foremost among the State boards of health of America in leading local authorities to improve their water and sewage works in an efficient and economical manner. Its influence has extended, not only to other States, but also to numerous places throughout the civilized world. The Massachusetts Institute of Technology has exerted a less direct influence; but, as a training school for many who have taken a prominent part in improving water and sewage works, this institution and a number of its teaching staff have achieved results which will be more fully appreciated as the years go by.

While the experimental method so successfully applied in the student laboratory may in its way call for just as conscientious and diligent effort as when applied to projects involving immense sums of money, yet the responsibility associated with the latter is far greater. It is necessary, in carrying out successfully these large practical problems, not only to draw correct conclusions from full representative premises of a complicated nature, but also to adjust the project to a reasonable business basis, to make it fairly well understood by non-technical officials and citizens, and to defend it from the obstructionists who, for political or selfish reasons, cross the pathway of nearly every large public enterprise. In meeting these requirements there has been called forth a series of efforts which are of great significance to the public from the sanitary and financial standpoints, and which form notable achievements in the field of applied science.

Benefits of Improved Sanitary Works.—Improved water and sewage works of course do not explain by any means the entire improvement which for the past quarter of a century has been so characteristic of the sanitary conditions of a majority of the civilized communities of the world. But, illustrative of the scope of such improvements under the guidance of wise sanitary authorities, it is of interest to point out the markedly decreased death rates in Massachusetts from water-borne diseases, of which typhoid fever is the typical, but not the only one.

TABLE I.

DEATH RATES PER 100,000 POPULATION FROM TYPHOID FEVER IN THE STATE OF MASSACHUSETTS BY FIVE-YEAR PERIODS FROM 1881 TO DATE.

Period.	Rate.	Period.	Rate.
1881—1885......	41	1896—1900......	26
1886—1890......	46	1901—1904......	19
1891—1895......	34		

Two of the 500 h.-p. Boilers.

What is true of Massachusetts is in a general way true of many sections of both America and Europe where the population has become quite dense, and demands for water and sewage works of satisfactory character have pressed forward for attention in recent years. No attempt will be made here to show the great sanitary benefit derived from other factors than improved water supply and sewerage, as this matter is clearly set forth in standard works upon sanitation and official reports from various quarters of health authorities who deal with the accomplishments of the modern health officers.

It is sufficient here to present clearly to the reader the thought that modern sanitary science has greatly increased the comfort and safety of living. In various cities the reductions in death rates have been far greater than as given above for the State of Massachusetts. This is especially true in cities where badly polluted water supplies have been replaced by improved supplies. Numerous instances of this sort are on record where annual typhoid fever deaths of 50 to 100 per 100,000 have been reduced to about 20. These cities include not only those now receiving upland waters from unpolluted sources, and ground water, but also those having filtered water from earlier but polluted sources; for example, Lawrence, Mass., Albany, N. Y., York, Pa., and Lorain, Ohio. Intestinal diseases other than typhoid fever have been so reduced as to lower the general death rate materially. For low lying communities like New Orleans modern drainage has lessened notably the general death rate, and sewerage brings safety as well as comfort to communities, among other ways by eliminating privy vaults and the likelihood of disease transmission by flies, etc.

As to financial considerations, it is difficult to present the full significance of this feature to the general reader without statistics which would be out of place in a short general article like this. Usually water purification projects proper cost about $3 to $5 per inhabitant served; but pumping, force mains, conduits, reservoirs, and other associated appurtenances sometimes increase the investment to $15 to $25 per capita. Sewage purification frequently is more expensive than water purification. Upon capitalizing the operating expenses, it is found that modern sanitary works, while involving only small costs for the individual, reach sums of millions and tens of millions of dollars for our large cities. The solution of these problems has brought many added duties to sanitary authorities, to professional men who assume the responsibility for constructing and operating the required works, and to the educational institutions which give technical training to young men desirous of entering this field of work.

New Conditions Encountered.—Twenty-five years ago the large cities of America were, of course, provided with public water supplies, and many of them had progressed considerably in adopting sewerage systems, although these latter now appear to have been more or less crude. Sewage purification plants and water purification plants, with perhaps half a dozen small and scattered exceptions, were practically unknown. A large proportion of the water supplies, especially in the Central West, were seriously objectionable in the excessive quantities of mud which they carried, and so different in their nature from the comparatively simple filtration projects of Europe that engineers naturally hesitated for financial reasons to attempt their construction, to say nothing of the question whether they would be able to give satisfactory service. The bacterial and hygienic aspects of these problems, which are now recognized to be of so much importance, were almost unknown. In fact, the germ theory of disease had not risen to general acceptance.

The medical man interested in public health knew in a general theoretical way what he wanted, but he was ordinarily unable to state his requirements in a manner understood by the engineer or by the taxpayer. Engineers were able to build any reasonable works, but were unable to learn in terms of the constructor what was required with sufficient definiteness to allow them to make even preliminary sketches and estimates of cost. The chemist and bacteriologist occupying an intermediate position produced with ill-suited methods analytical data full of mystery for everybody.

Misunderstanding continued until men interested in various lines of applied sanitary science co-operated in a manner to make themselves mutually understood. The successful movement to this end, at least in the United States, had its inception chiefly in Massachusetts some twenty years ago. It has resulted during the past dozen years in some notably well-balanced designs for American water and sewage works, which have demonstrated their sound merit in practice. In this article it is the endeavor to outline the development of this aspect of experimental methods.

Experimental Methods in Massachusetts.—The experimental methods which have been put in practice in America so much in recent years may be defined as the bringing together of reliable preliminary data from the engineering, chemical, bacterial and hygienic standpoints, in order that efficient sanitary works may be built for a wide range of local conditions within the limits of reasonable cost; and if data are inadequate for fair assumptions, then the procuring of the needed data by practical tests on a small scale.

It is the Massachusetts State Board of Health to which credit is principally due for developing this method to serve as a guide for such works. In 1886, when the present board was organized, one of its first steps was to establish the Lawrence Experiment Station, whereby data were to be secured to show the best means available under various local conditions for purifying water and sewage. The legislature enacted that this board should serve as a sanitary tribunal, before which the local authorities should place their projects for water and sewage works, and whose approval was requisite before the State authorities granted the local authorities permission to issue bonds for their construction. This experiment station has been in continuous service since the autumn of 1887, and has attained a high reputation among various workers in the field of sanitary science throughout the world, in addition to fulfilling its main purpose of aiding the citizens of Massachusetts in economically improving their public works, whereby to a material degree the health and comfort of the people of the State have been enhanced. These results are so well known that it is needless here to go into detail.

The classical investigations at Lawrence, as set forth in the annual reports for the past fifteen years, have undoubtedly done more than any other series of investigations in the world to place the science of purifying water and sewage on a sound practical basis. It is true that earlier workers abroad had previously taken important steps along some of these lines, and that sand filtration of water had for many years been in use. But they did not secure comparable parallel data from the engineering, chemical and bacterial standpoints with anything like the completeness obtained at Lawrence, whereby the laws governing successful practice could be broadly stated for a wide range of conditions.

Not only has the Massachusetts State Board of Health availed itself of a testing department, but with other departments it has placed itself in a position to utilize such data advantageously. This has been done by an analytical department procuring data at frequent intervals as to the character of various water supplies, rivers, effluents, etc., and, more especially, by a well-trained engineering corps which applies the various data to the needs of each problem coming to the attention of the board.

That the Massachusetts State Board of Health handles well the work coming within its jurisdiction is conceded by all in a position to know of it intimately. It is true that the board is criticised for not devoting itself more enthusiastically to studies of methods finding favor elsewhere, but this criticism has little to support it. The board properly confines itself to the solution of problems within the State, and of course does not consider it necessary to do more than keep generally familiar with other methods, no matter how suitable they may be for work elsewhere.

Experimental Methods Elsewhere in America.—In water purification the Massachusetts problems are, generally speaking, much easier and simpler than those of the Central West and South, where enormous quantities of silt and clay complicate the necessary works for treating the water, and add materially to the cost as regards both construction and operation. In a manner similar to the procedure at Lawrence, these problems were worked out at Louisville, Pittsburg, Cincinnati and New Orleans. At numerous other places the experimental method has been used in adapting more strictly the design of works to local conditions, especially in the preliminary treatment of turbid waters (Philadelphia and Harrisburg), the removal of color from surface waters (Providence), of iron from ground waters (West Superior), the softening of hard waters (Columbus), and the removal of tastes and odors (Reading and Springfield). These problems have all been carefully studied in small test devices for securing data necessary for advantageous design and operation.

Sewage purification has also been studied under various local conditions at several places, especially at Worcester, Mass.; Pawtucket, R. I.; Berlin, Ont.; the Institute of Technology, Boston; Columbus, Ohio, and Waterbury, Conn. In most cases the sewage studies have arisen because of inability or great expense in applying the well-known Massachusetts method of intermittent filtration through sand, or because of peculiarities of the local sewage.

A partial list of the more prominent investigations as to purifying water and sewage, with dates and approximate costs, is given in Table II.

TABLE II.

LIST OF SPECIAL INVESTIGATIONS ON WATER AND SEWAGE PURIFICATION.

Place.	Date.	Work.	Approximate Cost.
Lawrence, Mass.	1887 to date	Water and sewage	$175,000
Providence, R. I.	1893—94	Water	5,000
Louisville, Ky.	1895—97	“	47,395
Reading, Pa.	1897	“	1,500
Pittsburg, Pa.	1897—98	“	36,286
Cincinnati, O.	1898—99	“	41,588
W. Superior, Wis.	1898—99	“	2,000
Washington, D. C.	1899—1900	“	8,000
Richmond, Va.	1900	“	2,000
New Orleans, La.,	1900—1	“	23,606
Worcester, Mass.	1900 to date	Sewage	37,000
Philadelphia, Pa.	1900—5	Water	172,000
Springfield, Mass.	1901—3	“	18,000
Harrisburg, Pa.	1903—4	“	25,000
Mass. Inst. of Technology, Boston	1903 to date	Sewage	20,000
Columbus, O.	1904—5	Sewage and water	44,004
Waterbury, Conn.	1905 to date	Sewage	10,000
Total			$668,379

It is not pretended that the above list is complete. In fact, there are other tests which, while small and of short duration, have had much to do with professional opinion. Perhaps the most important were demonstrations at Louisville and St. Louis, many years ago, that plain sand filtration was incapable of treating the muddy Ohio and Mississippi River waters after plain sedimentation in large basins.

The benefit derived from the experience of the owners of proprietary devices cannot be overlooked—especially in regard to various appliances of mechanical filters which occasioned the expenditure of much money before being brought to their present state of development. At Louisville alone the five competing filter companies spent more than $50,000. More recently their devices, when tested, have been purchased at the beginning.

While this paper is devoted essentially to methods of purifying water and sewage by works partly or wholly of artificial construction, mention should be made of the important advances in the allied field of water supply from storage reservoirs, and the disposal of sewage by dilution. Among the more prominent investigations of this kind should be stated those field surveys and laboratory studies made in connection with the Chicago Drainage Canal, the additional water supply of New York City, the improvement of the Charles, Mystic and Neponset Rivers in Massachusetts, and foreshore pollution along the Massachusetts coast. Several hundred thousands of dollars have been expended on these investigations.

Object and Advantages of Experimental Methods.—The purposes of applying experimental methods to problems of water and sewage purification are chiefly threefold, as follows:

1. To provide data for the official and technical authorities, to enable them to adapt new works most advantageously to the local conditions, and to indicate dimensions and other physical conditions permitting contract plans to be prepared and the cost of construction to be approximately estimated.

2. To educate the non-technical public, who as citizens and taxpayers are interested in public works.

3. To provide data so that the officials can operate effectively the works after they are completed, and forecast the approximate cost of operation.

In regard to the first object accomplished, that of enabling city officials and their technical advisers to design economically works of a suitable character, it goes without saying that this has been of the greatest importance, and is a strong factor in explaining the rapid strides in successful sanitary works accomplished during the past few years. It has frequently been the advice of technical men, in dealing with problems which differ from those successfully solved elsewhere, to make tests for a year or so at a cost approximating the interest for one year for the works contemplated. In this way the cost of errors and unbalanced designs has been largely minimized, and the efficiency has been increased. In the field of water and sewage purification the information and experience now available are sufficient in a majority of cases to enable these problems to be advantageously handled by experienced workers along these lines. There are some problems, however, that still can be advantageously treated by the experimental method. They refer especially to sewage problems in which trade wastes are involved, and to water problems where the composition of the water is quite unusual in some particulars on frequent occasions. From the technical standpoint, however, the field of water and sewage purification, broadly speaking, has passed beyond the experimental stage, and the advances, both as to efficiency and economy, are largely to be gained, not from experimental plants, but by the careful and more systematic operation of works in practice. Such studies will, of course, lead to improvements which can be taken advantage of in the construction of new works, and will gradually bring to a higher plane of excellence the art of water and sewage purification on its present scientific basis.

It is frequently said that communities progress in proportion to the advance in knowledge of the average citizen, or to the mean knowledge of the community as a whole. There is a good deal in this, and it brings forcibly to mind the necessity of educating the public as to what improved sanitary conditions really mean, and of letting them ascertain for themselves what can be accomplished along these lines in the field of applied science. Non-technical people have a natural aversion to the word experiment, notwithstanding the aid derived from devices which not improperly may be termed experimental. While the term "experiment station" from its use at Lawrence and a few other places seems to have a firm footing in some localities, it is gradually giving place to the term testing station. This is a much preferable expression in many ways, as it disarms the criticism of many who seem to think that these investigations are conducted in a "hit or miss" manner, much after the fashion of the early inventors. This is not so, as experimental methods, as now ordinarily applied to water and sewage works, are aimed at testing procedures found successful elsewhere, but which may require adaptation to local conditions in regard to some details. Their magnitude, while relatively small for reasons of economy, is still much greater than that which seems to be taken for granted by numerous citizens, who associate the word experiment with a test tube, or with a mechanical device which is so imperfect that no one dares to build it on a large scale without further experiments. The methods of purifying water and sewage have now advanced to a degree where the phrase testing station in new projects will unquestionably displace experiment station; and the testing of these processes where unusual conditions are expected will assume a dignity comparable with that of the regular departments which systematically test cement, steel and other materials used for building purposes. In fact, it is interesting to note that the laboratories at many testing stations have been utilized regularly for testing construction materials.

Where water and sewage purification projects involve hundreds of thousands of dollars or more for construction costs, the so-called experimental methods, as applied in accordance with the foregoing statements, have given wonderful courage in many places to officials who otherwise would very naturally have been in a hesitating frame of mind, and inclined more to listen to the "doubting Thomases" who, in all communities, for selfish or other reasons, appear as opponents and obstructionists to modern sanitary works. Even if the technical advisers of the projects were not assisted by such data, it is quite likely that the testing station for many projects would indirectly in this way do far more good than the cost involved, in saving lives and in hastening the day when communities will meet their problems in accordance with the best information available.

In speaking of the educational benefit derived from applying experimental methods to water and sewage works, the technical men, especially those in charge of the tests, have an important duty to perform in teaching non-technical officials, and various citizens who are interested in the work, the fundamental principles of the process involved, and in assisting them in ascertaining what practical works would mean, both hygienically and financially. Along this general line the Institute of Technology has played an important role, largely through having had for many years on its teaching staff a man who to an extraordinary degree possesses the faculty of getting fundamental truths of sanitary science before his hearers in such an attractive manner that they never forget them. It is the belief of the writer that the work accomplished by Prof. Sedgwick along this line is unequaled by that of any other man in this country, either in educational or other lines, and that this fact in a few years will be far more widely realized than at present, when his younger pupils throughout the country reach an age where their work will be felt in the communities in which they live. This influence is already to be found in many unexpected places, and forms a wonderful tribute to the success accomplished by Prof. Sedgwick in one of his many lines of usefulness.

After water and sewage purification works are constructed, it is imperative that they shall be operated in an intelligent and efficient manner. The benefit of this has long been demonstrated in Europe, and the absence of such supervision in many places in America shows the folly of careless and indifferent management. No matter how well water and sewage purification works may be designed and built, there is no engineer who can give assurance that the results accomplished will be satisfactory unless the works are well managed. Not only must the works produce a result which is satisfactory from a scientific standpoint, but their behavior should be put before the citizens in a way that will inspire confidence. When fair-minded citizens as a mass continue to lack confidence in works of this type the latter cannot be called an unqualified success, no matter how fully scientific facts may show their adequacy.

The Massachusetts Institute of Technology instituted the plan of especially training young men along technical lines, so that they might become competent to serve as superintendents for water and sewage purification works. In this pioneer work they are entitled to great credit, and their example is already being followed by similar institutions elsewhere. This is an important field of technical education, as a majority of such technically educated men in the future will be connected with the management, rather than with the construction, of works of this type.

In passing, it may not be amiss to say that the technical managers of works of the type under consideration must have other qualifications than those of a scientific nature. They must be able to maintain amicable relations with executive superiors, to manage laborers, to keep records in a manner fairly comparable with the high degree to which the art of bookkeeping in large business houses has advanced, to prepare reports containing essential features in explicit but terse terms, and to make plain to non-technical men in both public and private capacity the more essential features of their own position and of the data by which their efforts show what is being accomplished. This type of specialists will naturally develop in efficiency as their responsibilities increase; but there is still much work for the technical schools to do in preparing young men more adequately for these duties.

As distinguished from the testing stations built solely for the purpose of tests, there is, of course, one other method of a somewhat experimental nature by which local data are used in determining whether large works are most advantageously constructed. I refer to the plan of constructing works gradually, or tentatively, and of using data from the operation of the first portion of the installation to serve as a guide in arranging the details of the portions subsequently to be built, and also in deciding upon the magnitude of the works sufficient for a given capacity or to serve for a given term of years. This is the style of works, from the experimental point of view, which frequently obtains in Europe, and which will obtain in some places in this country. As yet there has not been a wide application in America of such data obtained on a large practical scale, although, of course, they are availed of more or less in all works where extensions are required. This condition has been reached at several sewage works in New England, and the results of experiences in the field have been summarized by the Massachusetts State Board of Health. It is gratifying to state that practical results are in general conformity with the principles of water and sewage purification as developed by tests on a small scale.

Experimental Methods in Europe.—In Europe the water purification problems do not cover nearly so wide or difficult a range of natural conditions as those met in America. Filtration has in recent years not received as much attention experimentally as has been the case with sewage works. In earlier years, however, experimental methods had much to do with the development of water filters abroad. It is not to be forgotten, furthermore, that in Germany much good work during the past dozen years has been done in developing the most practical methods for removing iron from ground waters. At present the most interesting feature of water purification developments in Europe refers to the preliminary treatment for some of the river waters which are fairly turbid during freshets, and to efforts to sterilize water economically by ozone. The most notable instance of the former is at Suresnes, near Paris, where the Seine water below the metropolis is subjected to filtration six times, the first filters being of coarse gravel to effect clarification.

In England, which is the home of modern sanitary engineering, sewage purification works have received more attention than in any other country. The density of population in England and the relatively small size of its rivers have, of course, forced this condition at an earlier date than is generally true of other countries. While for some years the English have not contributed much on the subject of water filtration, their experience in the field of sewage purification far exceeds that of any other country. Experimental methods in one form or another have played an important part for half a century, beginning with efforts to utilize the manurial value of sewage. This is largely owing to the differences in various local conditions, especially topography, geology, and the composition of the sewage as influenced by trade wastes. Not only have the English conducted test filters and other processes of purification on a small scale, but they have also gathered many data of great value by the operation of their works in practice along lines which enable current experiences to be utilized in developing future works.

These data have been so universally obtained in conjunction with the operation of existing works in practice that it is very difficult to ascertain even roughly what their cost has been. The staff regularly engaged in operating the main works has secured the technical data, so that the expense has been confined to building the test devices, relatively small in size, and to a little extra labor for operation. The large mass of valuable testimony published in numerous municipal reports and by the Royal Commission on Sewage Disposal shows what a fund of knowledge has been accumulated at London, Salford, Sutton, Exeter, Burnley, Accrington, Huddersfield, Leicester, Birmingham, Bradford, Devizes, Hanley, and other cities, and which for most places has been obtained with almost no special fund devoted to testing purposes, comparatively speaking.

At Leeds the unusually thorough sewage tests made during the past eight years received appropriations of about $150,000, some two-thirds of which has been actually devoted to that purpose. Manchester has also expended quite large sums for experimental purposes, although, for the reasons above stated, the expenditures were by no means commensurate with the information obtained. The Royal Commission on Sewage Disposal in England is understood to have an appropriation of about $55,000 for the expenses of its own staff and the traveling expenses of the numerous witnesses who have appeared before it. There are also special river boards and county councils, with excellent technical staffs, which gather many valuable data.

In France sewage purification has been the subject of experimental study, beginning with the labors of Mille in 1868 at Gennevilliers. These tests resulted in the establishment of the present sewage farms of Paris. Within the past few years the biological methods of purification have received attention both from the city of Paris and from the Department of Agriculture. The latter has a general supervising control over water and sewage matters outside of Paris, and is devoting an appropriation of about $60,000 to such investigations. Thus far these studies have been made by Professor Calmette at Lille, as set forth in his interesting progress report of last autumn.

In Belgium the government is paying particular attention experimentally to the treatment of trade wastes at a special station devoted to that purpose at Verviers.

The government of Holland established, in 1904, a sewage testing station at Tilburg, the cost of which to date is approximately $15,000. No reports have yet been published. Several ozone plants have been tested in Holland, and the city of Rotterdam is now arranging to test a mechanical filter on the local river water supply.

In Germany numerous experiments have been made upon the sedimentation of sewage for purposes of clarification, and the so-called biological methods have been studied for some years, beginning in 1895, when a testing station was established by Professor Dunbar at Hamburg, which station is still in operation. In 1901 the Prussian government established a permanent organization for testing water and sewage purification methods. This "institute" has gathered together and published the more important data as to experiences in other countries, has conducted several important sewage testing stations in the suburbs of Berlin, and has collated many useful data as to the sanitary works of the cities of Prussia and neighboring territory. This department has an annual appropriation of about $30,000 for testing, inspecting, analytical and clerical purposes. The sum devoted to testing purposes varies, but is materially supplemented by the arrangement of conducting investigations for various local authorities, the expense for which is borne in part by the community benefited. The department also established the custom of officially examining proprietary devices, largely at the expense of the owners in cases where the devices seem to possess sufficient merit. In this way a mechanical filter of the Jewell type was recently tested at the Muggelsee plant of the Berlin water works. The same filter is now being tested on the colored water supply of Königsberg.

The relative amounts of suspended matters deposited from sewage at different velocities have been studied carefully under varying local conditions at Frankfurt, Cassel, Hanover and Cologne, as shown by the data published in municipal reports and the technical press. In these cities, as in England, it is difficult to ascertain the cost of the tests, because so much of the work was done by the regular staff of the technical authorities of the cities. The scope of the tests has probably been greatest at Frankfurt, including means for most easily removing sludge, its partial drying by centrifugalization, and its ultimate disposal by incineration after mixing with the city refuse. About $60,000 has been spent at Frankfurt on these and other sewage tests, including filtration, within the past dozen years or more.

Prof. Dunbar's activities in the field of sewage purification have by no means been confined to Hamburg. His publications show that he has advised the authorities at Mühlhausen, Stuttgart, Beuthen, Unna, Leipzig and other places. In nearly every instance he has taken advantage of experimental data to ascertain local conditions. Leipzig and Chemnitz in Saxony are now conducting sewage tests, the appropriations for which are about $17,000 in each case, with the engineering and analytical data secured by men regularly employed by the city.

This brief record of experimental methods as applied to water and sewage purification can hardly be brought to a close without reference to trade wastes. This feature in aggravated cases complicates the design of sewage works and adds materially to the costs of operation. Various industries require special consideration, as shown by the efforts of the river boards to minimize the effect of trade wastes in the streams of Lancashire and Yorkshire, England. The removal of fats has perhaps received the most attention along this line—especially in Berlin, Cassel and Chemnitz in Germany, Verviers in Belgium, Roubaix and Grimonpont in France, and Bradford, Manchester and Oldham in England. Numerous mill owners also recover grease from their waste water. The extent of some of these investigations is indicated by the fact that at Cassel a private company is said to have spent considerably more than $100,000 in unsuccessfully endeavoring to fulfil a contract for extracting fats from the city sewage. The only large place where the entire city sewage is regularly treated for grease extraction is at Bradford, England.

Moving a House from Michigan to Massachusetts.

By Howard S. Knowlton.

The removal of buildings from one site to another without dismantling is a matter of everyday work to contractors who have specialized in this line. Much less frequently does it happen that even small buildings are torn down, transported and rebuilt on new sites, so that the taking down of a large brownstone mansion in Marquette, Mich., its shipment by rail and re-erection at Brookline, Mass., is a matter of unusual interest. The house is owned by Mr. J. M. Longyear, a capitalist interested in mining and timber lands in the Lake Superior district; and formerly occupied a site overlooking Lake Superior at Marquette.

The body of the house is built of the stone known as "Marquette raindrop," the trimmings being of Marquette brownstone. As the result of a decision on the part of the owner to move the house to Brookline, the work of demolition was begun about March 1, 1903 at Marquette. Some 35 men were required for the work. The architectural features of the exterior were preserved in the Brookline location. On demolishing the house at Marquette, the arches were numbered and marked consecutively, as were the piers and courses of the balustrade. Each stone, except in the body of the house, was numbered according to its order of location in course, arch or pier, and the number or letter of the arch, course or pier was also placed upon the stone. Photographs were also taken of the numbered stones before demolition took place, and one was also taken, as shown herewith, of a typical window casing, bay, sill and cornice, to facilitate erection in Brookline. In the tearing down of the house two hand derricks were used, together with a rubbish slide. The house was surrounded by sandy ground, so that a large percentage of the stones could be dropped from their original locations without danger of chipping, cracking or breaking. Carved and molded pieces of stone work were crated for shipment, and even the large stone fence which surrounded the grounds at Marquette was taken down, shipped to Brookline by freight and re-erected. By June 1, 1903, the house had been entirely demolished at Marquette, and the last shipment was under way.

About 190 freight cars of various types were required for the shipments. These cars were despatched from Marquette as they were loaded, and it is said that the cost of the freight shipment alone was in the vicinity of $30,000, or possibly one-tenth of the original cost of the house. The cars were hauled in the main through Canada, over the Canadian Pacific R. R., the total distance from site to site being about 1,200 miles. Windows, moldings, door frames and the like were also shipped by freight.

The new site of the house is the summit of Fisher Hill, Brookline. Excavation was begun here Aug. 1, 1903, and the house was occupied by its owner about April 15, 1906. The main house is 120 ft. long by 60 ft. wide, with an ell 63 ft. long by 48 ft. wide for a kitchen, servants' dining room and laundries. The ell was added to the newly erected house, as was a music room on the north side, about 60 ft. by 22 ft., and a bowling alley, 135 ft. by 21 ft. under the south terrace. The house is three stories in height, with a finished attic. The additions were made by using more stone of the same kind. All chimneys were used in their original places, two of the chambers were provided with the same interior finish as in Marquette, and the "octagon hall" was largely reproduced. Many of the body stones were used interchangeably. The house was taken down and removed to Brookline and re-erected, for personal reasons rather than otherwise. The architect in charge of the work was Mr. D. F. Charlton, of Marquette, the builder who did the work being Mr. Chas. C. Van Iderstine of that city.

Letters to the Editor.

CORROSION OF STEEL BRIDGES.

SIR: In the issue of The Engineering Record for July 7, Mr. A. C. Barrow proposes as a method of ascertaining the present strength of a bridge that has deteriorated by rust that a load test be made and the deflection measured. He suggests that the amount of deflection would be a measure of the unit stress in the members and would be an index of the present strength using, presumably, the calculated deflection of a properly proportioned bridge as a unit.

There are some drawbacks to such a method of determining the strength of a bridge whether new or old, and the sum of the information thus obtained would be practically worthless, unless it were supplemented with a complete knowledge of the general design and details of the bridge.

In the first place, the deflection, except in the case of long or shallow spans, would probably be so small that it would be difficult to measure it with sufficient accuracy to make the relative values reliable. Many old bridges are high, short-truss spans where the deflection would be especially small.

In the second place, the deflection would measure only the general unit stress in the members. A detail may be on the verge of rupture and yet contribute but little to the stretch of the member and the consequent deflection of the truss. The gross area of a member for nearly the full length might be a certain amount, while its net area may be only a fraction of this amount. I have met with tension members in an old bridge that were composed of two angles and a plate, and the plate had no end connection whatever.

A bridge that has been affected so badly by rust as the one referred to by Mr. Barrow would probably be rusted more in the details, where the parts are lapped on each other and perhaps covered by the floor, than it would along the main members. As intimated, it is the main body of the member and not the detail (excluding play in pin holes) that contributes the greater part of the deflection. As for play in pin holes, this would all be taken up in the bridge by the dead load and only the deflection due to live load could be measured in a test.

In addition to this there are members that do not receive their maximum stress under the full load on the bridge. Weakness in these would not show up in the general deflection of the span, and deflection due to any of these could not be isolated from that due to the other members.

The only apparent way available to determine the present strength of a bridge is to measure all of the sections and details at their thinnest parts, if rusted, and to calculate the unit stresses.

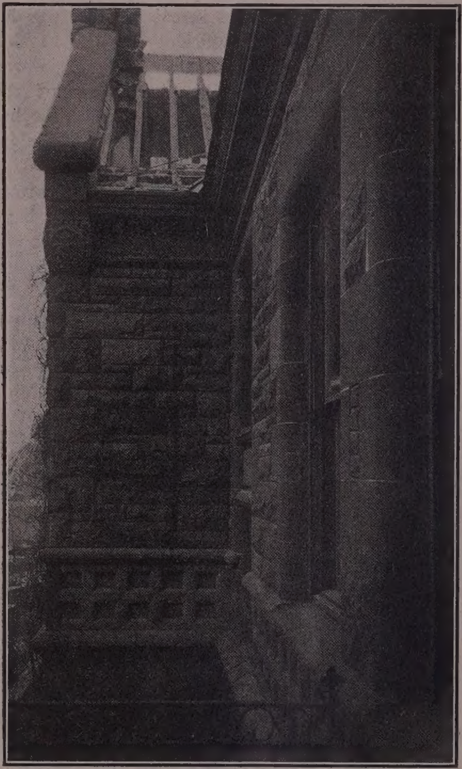
Yours very truly, EDWARD GODFREY.

Pittsburg, Pa., July 10.

CONCRETE COLUMNS.

SIR: In an editorial of recent date you kindly commented upon some notes of the writer's in regard to the design of concrete-steel columns reinforced with rolled shapes. The writer feels, however, that his position was not fully understood and begs the privilege of a little further discussion.

In the first place, the column he had in mind when writing was the one described, consisting of two I-beams, connected by occasional batten plates and filled with concrete. This concrete then has but little hold upon the steel except that it has imbedded in it an occasional rivet head and batter plate and the load transmitted from the one to the other amounts to the crushing value of the concrete under these projections, together with an indefinite amount due to the adhesion of the concrete to the smooth surface of the beams. If bearing plates are used at the splices the concrete will shrink away from them unless unusual precautions are taken. The floor beams and girders will rest upon brackets, transmitting their load directly to the steel. The continuity of the beams will be broken at the columns and we have as a result a mixed type of construction, impossible of satisfactory calculation, though of course easily made heavy enough to carry the required loads. More serious objections may be found to the star strut type of angle concrete columns frequently used by certain eastern architects. This consists of four angles riveted back to back and surrounded with concrete. The steel is so placed that the radius of gyration is a minimum; the concrete of the columns, instead of being in one large section is cut into four small independent masses, any one of which is liable to receive more than its proper share of the load and be in danger of buckling. The continuity of the beams is entirely broken. The only excuse that can be offered for this type of design is that of satisfying the architect's desire for a small column. It seems to the writer, however, that this end is obtained at a very great cost, that of weakening the entire construction.



Typical Window Casing, Bay, Sill and Cornice.

The type of column suggested in the editorial to which I have referred, however, is a logical column, consisting as it does of four angles in the corners of the column, latticed together so that they are capable of carrying a maximum load without the concrete. They work with the mass of concrete in the interior and strengthen it. The area of the steel sections is not excessive as compared with the total area of the column, and the numerous projections, such as rivet heads and tie plates make it reasonably certain that the two materials will work together in accordance with their respective ratios of elasticities. The only danger lies in making the angles so large as to leave insufficient connection between the beams and the concrete within the column.

It is necessary, too, that considerable space be left between these angles for the proper installation of top reinforcing bars.

Yours very truly,
F. F. WELD.

Detroit, July 10.

A FORMULA FOR REINFORCED CONCRETE.

SIR: Your correspondent, Mr. W. W. Pearse, in his communication on "A Formula for Reinforced Concrete," printed on page 28 of your issue of July 7, seems to have fallen into the same error as did Mr. Farrar, on page 382, of the issue of Mar. 17, 1906; in that he makes the moment of the tension in the steel about the neutral axis equal to that of the compression in the concrete about the same axis (see third line below the diagrams in the second column of page 28). Mr. Farrar corrected this mistake on page 436 of the issue of Mar. 31, 1906.

Yours truly,
I. P. CHURCH.

Ithaca, N. Y., July 9, 1906.

LOADING OF HIGHWAY BRIDGES.

SIR: The method suggested in Mr. A. C. Barrow's letter of placing a known load on a highway bridge and noting the deflection to determine the damage done by the rust would not give the information desired. One reason is that rust does not act uniformally and members are eaten away more at one place than at another. But suppose that rust were to destroy the same thickness of metal on each piece in the bridge, and that we had two plates designed to be stressed to the same intensity. Let one of the plates be ½ in. and the other ¼ in. thick, and the rust removed ⅛ in. Then the stress in the original ½-in. plate would be increased one-third, while in the original ¾-in. plate the stress would be doubled.

A careful inspection of the details of the bridge by a structural engineer would determine the safety to a certain extent; and a test loading would show that its strength was at least equal to that amount.

A marked example of the action of rust that the writer recently noticed, is in the posts of the first free highway bridge erected in Pittsburg. Where the posts pass through the asphalt pavement the rust has eaten a large part of the metal while the rest of the posts are in good condition.

Yours truly, C. E. SHEARER.

South Memphis, Tenn., July 12.

THE NEW SIMPLON TUNNEL, which was recently opened to traffic, is being operated with little difficulty from the natural rock heat that is encountered near the middle portion. At the same time, the ventilation has proved very satisfactory, in spite of the use of the ordinary coal-burning locomotives which are required, owing to the impossibility of operating with the new electric motive power, until the locomotives are specially insulated and equipped to withstand the moist vapors encountered. The temperatures experienced in the cars range as high as 80° Fahr. near the middle of the tunnel and correspondingly lower near the portals, but owing to perfect mechanical ventilation this does not prove objectionable, and the gases from the locomotives are said to be nowhere evident. The entire trip from Domodossola, near the Italian portal, to Brig, on the Swiss side, requires but little over an hour, at ordinary operating speeds. The unfortunate feature of the tunnel conditions is the condensation of moisture from the heated air near the middle on the cooler surfaces of the cars and equipment passing through, this condition having rendered the electrical operation troublesome until it can be provided against by enclosure of the apparatus liable to be affected.